President’s Council of Advisors on Science and Technology (PCAST)

Science and Technology to Ensure the Safety of the Nation’s Drinking Water
Workshop

Wednesday, May 18, 2016

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American Geophysical Union, Conference Room A
2000 Florida Avenue, N.W.

8:30 am **Breakfast Available**

9:00 am **WELCOME AND PARTICIPANT INTRODUCTIONS**
Co-chairs: Rosina Bierbaum and Chris Cassel

9:15 am **OPENING REMARKS**

John Holdren
Assistant to the President for Science and Technology
Director
Office of Science and Technology Policy

9:30 am **DRINKING WATER QUALITY – OVERARCHING PERSPECIVES**
What is the state of the Nation's drinking water systems? What gaps exist in the ability to provide safe drinking water? What additional resources are needed to address current and future challenges?

Panel & Discussion Moderator: Rosina Bierbaum

Tom Burke
Science Advisor
Environmental Protection Agency

Michael Beach
Associate Director for Healthy Water
Centers for Disease Control and Prevention

Contact on day of meeting: Diana Pankevich at (202) 250-0090 or (202) 295-7732

Nancy Sutley
Chief Sustainability and Economic Development Officer
Los Angeles Department of Water and Power

Steve Via
Director of Federal Relations
American Water Works Association

Open discussion

10:30 am **BREAK**

10:45 am **COMPARING RISKS IN DRINKING WATER**
What is the current state of scientific understanding of the risks associated with contaminants in drinking water? Is there sufficient data and research to support the prioritization of contaminants?

Panel & Discussion Moderator: Ed Penhoet

Lynn Goldman
Professor of Environmental and Occupational Health
George Washington University

Joan Rose
Co-Director of the Center for Advancing Microbial Risk
Michigan State University

Gene Phillips
Chief, Bureau of Environmental Health and Radiation Protection
Ohio Department of Health

Bob Perciasepe
President
Center for Climate and Energy Solutions

Open discussion

11:45 am **GATHER LUNCH**

12:00 pm **KEYNOTE:**

Upstream and Downstream: Tracing the Causes and Measuring the Effects of Contaminated Water in Flint

Matt Davis
Professor of Public Policy
University of Michigan

12:30 pm **WATER SOURCES**

What types of insults to water sources lead to contamination? How can these be mitigated? How can science and technology improve monitoring to rapidly detect contaminants? How might water reuse improve drinking water quality?

Panel & Discussion Moderator: Maxine Savitz

Rhodes Trussell – *Challenges*
Chairman and Founder
Trussell Technologies, Inc.

R. Scott Summers – *Science and Technology Opportunities*
Professor of Environmental Engineering
University of Colorado, Boulder

Peter Grevatt – *Science and Technology Opportunities*
Director, Office of Ground Water & Drinking Water
Environmental Protection Agency

Open Discussion – How can the Federal government promote opportunities?

1:15 pm **TREATMENT PLANTS**

How can science and technology improve monitoring to rapidly detect contaminants? Are there mechanisms by which treating water at the plant can help mitigate potential downstream contaminations in the system?

Panel & Discussion Moderator: Maxine Savitz

Robert Renner – *Challenges*
Chief Executive Officer
Water Resource Foundation

Mark Benjamin – *Science and Technology Opportunities*
Professor Environmental Engineering
University of Washington

Paul Westerhoff – *Science and Technology Opportunities*
Professor, School of Sustainable Engineering and the Built Environment
Arizona State University

Open Discussion – How can the Federal government promote opportunities?

2:00 pm **DISTRIBUTION SYSTEM**

How can technology be used to better monitor conditions between the plant and the tap (e.g., residual disinfectant levels, corrosion by-products)? Are there innovative ways to distribute treated water while maintaining treated water quality and preventing future contamination? How can technology be leveraged to repair and/or replace pipes in a cost-effective manner?

Panel & Discussion Moderator: Dan Schrag

Philip Singer – *Challenges*
Emeritus Professor, Department of Environmental Science and Engineering
University of North Carolina, Chapel Hill

Orren Schneider – *Science and Technology Opportunities*
Manager, Water Technology, Innovation and Environmental Stewardship
American Water

Cathy Bailey – *Science and Technology Opportunities*
Director
Greater Cincinnati Water Works

Open Discussion – How can the Federal government promote opportunities?

2:45 pm **BREAK**

3:00 pm **PREMISE PLUMBING**

What is the state of the science for treating water in the home? How can technology be used to better monitor premise plumbing including at the tap? How can point-of-use devices for water treatment be better incorporated into traditional systems? How can technology be leveraged to repair and/or replace pipes in a cost-effective manner to maintain, or improve, water quality?

Panel & Discussion Moderator: Dan Schrag

Chad Seidel – *Challenges*
Technical Director, DeRISK Center
University of Colorado, Boulder

Dan Giammar – *Science and Technology Opportunities*
Walter E. Browne Professor of Environmental Engineering
Washington University in St. Louis

Open Discussion – How can the Federal government promote opportunities?

3:45 pm **SURVEILLANCE OF HUMANS**

How can detection of health risks related to contamination of drinking water be more quickly detected? How can surveillance efforts take advantage of new technology or data information to more quickly detect health risks?

Panel & Discussion Moderator: Ed Penhoet

Christopher Weis – *Challenges*
Toxicology Liaison
National Institute of Environmental Health Sciences

Phil Landrigan – *Science and Technology Opportunities*
Dean for Global Health
Icahn School of Medicine at Mount Sinai

Rad Cunningham – *Science and Technology Opportunities*
Epidemiologist
Washington State Department of Health

Open Discussion – How can the Federal government promote opportunities?

4:30 pm **TOWARD A 21ST CENTURY DRINKING-WATER SYSTEM**

What topics were not covered that could help in the development of an innovative clean drinking-water system? How can data and technology be leveraged?

Discussion Moderator: Rosina Bierbaum

Peter Gleick
President and Co-founder
Pacific Institute

Chris Kolb
President and Chief Executive Officer
Michigan Environmental Council

Open Discussion

5:15 pm **Wrap-up and Reflections**

5:30 pm **Adjourn**

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Workshop Participant List

PCAST Members

John P. Holdren, Assistant to the President for Science and Technology, Director, Office of Science and Technology Policy *(PCAST Co-Chair)*

Maxine Savitz, Honeywell (Ret.) *(PCAST Vice-Chair)*

Rosina Bierbaum, Professor, School of Natural Resources and Environment, University of Michigan *(Activity Co-Chair)*

Christine Cassel, Planning Dean, Kaiser Permanente School of Medicine *(Activity Co-Chair)*

Ed Penhoet, Associate Dean of Biology, University of California, Berkeley, Director, Alta Partners

Daniel Schrag, Sturgis Hooper Professor of Geology, Professor, Environmental Science and Engineering, Director, Harvard University Center for Environment, Harvard University

Participants

Cathy Bernardino Bailey, Director, Greater Cincinnati Water Works

Michael J. Beach, Associate Director for Healthy Water, Deputy Director, Division of Foodborne, Waterborne and Environmental Diseases, National Center for Emerging and Zoonotic Infectious Diseases, Centers for Disease Control and Prevention

Janice Beecher, Director, Institute of Public Utilities, Michigan State University

Mark Benjamin, Professor of Environmental Engineering, University of Washington

Thomas Burke, Deputy Assistant Administrator, EPA Science Advisor, US Environmental Protection Agency

Rad Cunningham, Epidemiologist, Washington State Department of Health

Matthew M. Davis, Professor of Public Policy, University of Michigan

Elizabeth A. Eide, Acting Director, Water Science and Technology Board, The National Academies of Sciences, Engineering, and Medicine

Daniel Giammar, Walter E. Browne Professor of Environmental Engineering, Department of Energy, Environmental and Chemical Engineering, Washington University in St. Louis

Peter H. Gleick, President and Co-founder, Pacific Institute

Lynn R. Goldman, Michael and Lori Milken Dean of the Milken Institute School of Public Health, Professor of Environmental and Occupational Health, George Washington University

Peter Grevatt, Director, Office of Ground Water & Drinking Water, Office of Water, US Environmental Protection Agency

Charles N. Haas, L.D. Betz Professor of Environmental Engineering, Department Head, Department of Civil, Architectural and Environmental Engineering, Drexel University

George M. Hornberger, Director, Vanderbilt Institute for Energy and the Environment

Mackenzie Huffman, Deputy Chief of Staff, Council on Environmental Quality

Chris Kolb, President and CEO, Michigan Environmental Council

Charles Kovatch, Deputy Associate Director for Water, Council on Environmental Quality

Kelly Kryc, Senior Policy Analyst, Energy, Water and Ocean Sciences, Office of Science and Technology Policy

Philip J. Landrigan, Professor of Preventive Medicine and Pediatrics, Dean for Global Health, Icahn School of Medicine at Mount Sinai

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Robert Renner, Chief Executive Officer, Water Research Foundation

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Joan B. Rose, Co-Director, Center for Advancing Microbial Risk Assessment, Michigan State University

Steven Rosenberg, Fellow in R&D, Dow Water and Process Solutions, Dow Chemical Company

Orren D. Schneider, Manager, Water Technology, Innovation and Environmental Stewardship, American Water

Mary Scruggs, Senior Advisor for Water Resources, US Department of Agriculture

Chad Seidel, Technical Director, DeRISK Center, University of Colorado Boulder

Philip C. Singer, Emeritus Professor, Department of Environmental Sciences and Engineering, Gillings School of Global Public Health, University of North Carolina at Chapel Hill

R. Scott Summers, Professor of Environmental Engineering, EVEN Program Director, DeRISK Center Director, University of Colorado Boulder

Nancy Sutley, Chief Sustainability and Economic Development Officer, Los Angeles Department of Water and Power

Rhodes Trussell, Chairman and Founder, Trussell Technologies, Inc.

Steve Via, Director of Federal Relations, American Water Works Association

Christopher Weis, Toxicology Liaison, National Institute of Environmental Health Sciences (NIEHS)

Paul Westerhoff, Professor, Civil, Environmental and Sustainable Engineering Program, School of Sustainable Engineering and the Built Environment, Ira A. Fulton Schools of Engineering, Arizona State University

Ali Zaidi, Associate Director for Natural Resources, Energy, and Science, Office of Management and Budget

Staff

Ashley Predith, Executive Director, PCAST

Diana Pankevich, AAAS Science & Technology Policy Fellow, PCAST

Jennifer Michael, Program Support Specialist, PCAST

Erika Kohler, Intern, PCAST

Announcing a New Study on Science & Technology for Drinking-Water Safety

APRIL 26, 2016 AT 10:07 AM ET BY ROSINA BIERBAUM AND CHRISTINE CASSEL

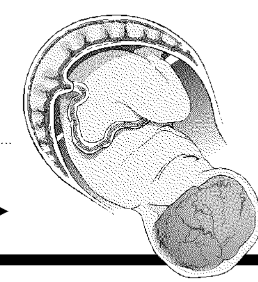
Summary:

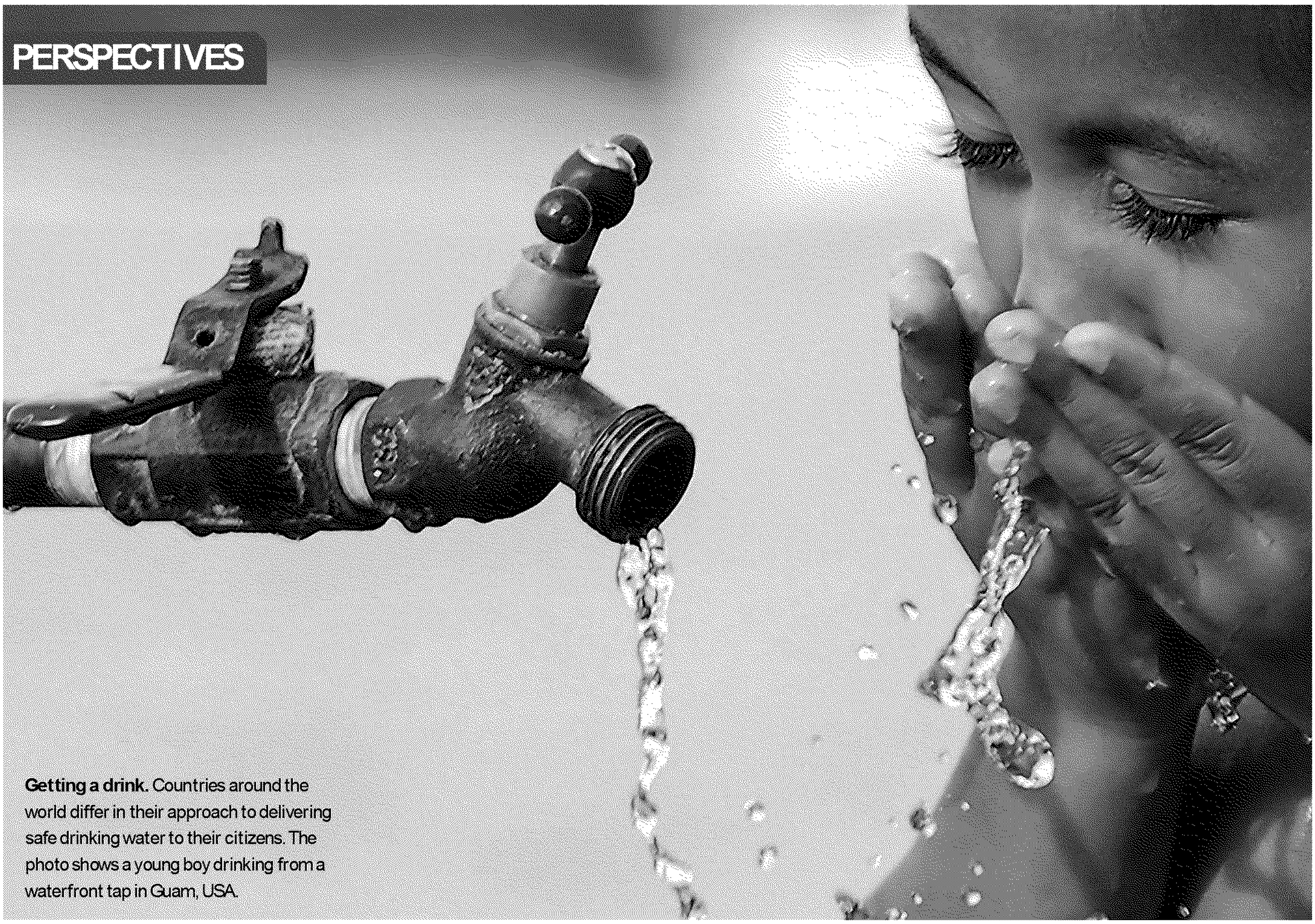
The President's Council of Advisors on Science and Technology Policy (PCAST) is beginning a new study to help inform action to ensure safe drinking water in the U.S.

The President's Council of Advisors on Science and Technology (PCAST) is beginning a new study of the science and technology relevant to ensuring the safety of the Nation's drinking water. After engaging a wide range of experts , PCAST will recommend to the President actions the Federal government can take, in concert with cities and states, to promote application of the best available science and technology to drinking -water safety, now and in the future. In its study, PCAST wil l look at how contaminants in water are detected and monitored from source to tap, how the associated risks are assessed and remediated, and how information about contaminant concentrations, risks, and remedies is communicated to officials and the public. In addition to identifying current best practices in these areas and the potential for propagating such practices more widely, PCAST will consider what lines of research and development hold promise for improving relevant capabilities and practices going f orward.

To assist in this effort, PCAST will seek input from Federal agencies including the Environmental Protection Agency, the Centers for Disease Control and Prevention, and the National Institutes of Health regarding data and ongoing research on water quality and public health. In conducting the study, PCAST will also tap the insights of non -Federal experts in the biomedical sciences, public health, water monitoring and purification, data collection and analysis, management of public water systems, and other pertinent areas. The results of the study will help inform future action to ensure that all Americans have affordable access to high -quality water when and where they need it.

Rosina Bierbaum and Christine Cassel are members of PCAST and co-chairs of the PCAST Working Group on Science and Technology for Safe Drinking Water.





PERSPECTIVES

Getting a drink. Countries around the world differ in their approach to delivering safe drinking water to their citizens. The photo shows a young boy drinking from a waterfront tap in Guam, USA.

WATER INFRASTRUCTURE

How do you like your tap water?

Safe drinking water may not need to contain a residual disinfectant

By **Fernando Rosario-Ortiz,**[1,2] **Joan Rose,**[3] **Vanessa Speight,**[4] **Urs von Gunten,**[2,5] **Jerald Schnoor**[2,6]

The expectation that tap water is safe has been sorely tested by the recent events in Flint, Michigan, where lead contamination has caused a public health emergency (*1*). Apart from contamination with heavy metals and other harmful substances, a key concern is the control of microbial contamination. To prevent microbial growth and protect consumers from pathogens from other sources, some countries, such as the United States, require the presence of residual disinfectant in drinking water. However, the presence of a disinfectant can lead to the formation of potentially carcinogenic disinfection by-products, issues with corrosion, and complaints based on the fact that people dislike the taste of disinfectants in their water (*2*). The experience of several European countries shows that such residual disinfectants are not necessary as long as other appropriate safeguards are in place.

From the early 1900s, the control of microbial waterborne pathogens, including *Salmonella typhi* and *Vibrio cholera,* led to a major reduction of waterborne diseases in the industrialized world. Filtration and chlorine disinfection reduced mortality in the United States substantially. But in 1974, chloroform, a probable human carcinogen formed by the reaction of chlorine with naturally occurring organic matter, was discovered in chlorinated drinking water. This discovery led to a debate about microbiological safety versus exposure to harm-

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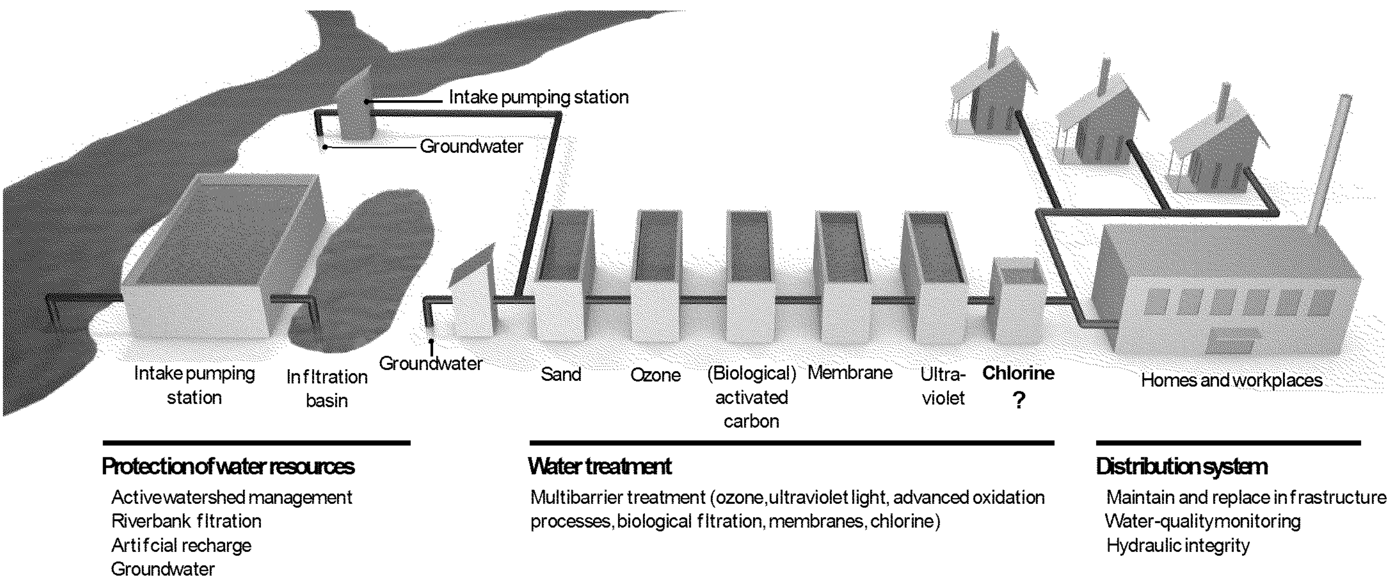
ful substances, and the overall effectiveness of disinfectants in the distribution system (*3*, *4*). Furthermore, disinfectants can contribute to the leaching of lead from pipes in older distribution systems (*5*).

In some European countries (including the Netherlands, Switzerland, Austria, and Germany), drinking water can be delivered to consumers without a residual disinfectant as long as there is adequate source protection, treatment, and maintenance of the distribution system to prevent growth of pathogenic bacteria and additional contamination events (see the figure). If one of these elements is missing or improperly managed, disinfectants are added to the distribution system to maintain a residual and a margin of safety.

In the United States, unprotected surface waters often serve as source water. Treatment includes coagulation, sedimentation, filtration, and disinfection with specific contract times. The water is then distributed to the consumer with a residual chemical disinfectant (chlorine, chlorine dioxide, or chloramines) as a last barrier against contamination.



Multibarrier approach to drinking water safety. Filtering through soil and/or sand-gravel aquifers protects source waters from many microbial contaminants. Well-controlled water treatment includes particle removal, disinfection, biological filtration, and removal of natural organic matter. Water can then be distributed to consumers without addition of a disinfectant residual, but with the capacity to do so in the event of leaks or repairs.

The choice between the two approaches is based on balancing the risk of microbial contamination, exposure to disinfection byproducts and the taste and odor of chlorine. In western Europe, eliminating the use of disinfectant during distribution certainly limits the formation of disinfection byproducts, but does it result in increased incidence of disease? And in the United States, how effective is maintaining a disinfectant residual in reducing the frequency of disease outbreaks? Also, what level of investment is needed to limit problems associated with old infrastructure, such as in the case of Flint? Estimates have ranged from tens of millions to $1.5 billion USD for Flint alone, and many other cities have similar infrastructure problems.

There is little direct evidence that disinfectant residuals have prevented drinking water–related disease outbreaks (including aerosol-associated cases of *Legionella*). A comparison of waterborne disease outbreak data from the Netherlands, United Kingdom, and United States shows that the Netherlands has a very low risk of waterborne disease. For these three countries, the rates of outbreaks per 1000 population in the last few years were 0.59, 2.03, and 2.79, respectively (*6*, *7*). It seems that the presence of a disinfectant in the distribution system does not guarantee lower rates of disease outbreaks. However, small groundwater systems that are not chlorinated and are typically used intermittently have caused the most recent outbreaks in the United States (*6*).

An additional consideration in the debate about disinfectant residuals is the robustness of the infrastructure against contamination events. In the Netherlands, at least half of the water distribution pipes have been replaced since the 1970s; as a result, pipe networks are, on average, 33 to 37 years old (*8*). Although there are regional differences, an estimated 22% of the pipes in the United States are more than 50 years old; the average age of pipe at failure is 47 years, and only 43% of pipes are considered to be in good or excellent condition (*9*). In the United Kingdom, as much as 60% of pipe inventory does not have a record of pipe age, and estimates of average pipe age are on the order of 75 to 80 years overall (*10*). The use of a disinfectant residual is required in the United Kingdom (*11*).

Leakage is one measure of vulnerability of the distribution system. It is as low as 6% in the Netherlands, compared to 25% in the United Kingdom and 16% in the United States (*8*, *12*, *13*). Generally, United States distribution systems have longer retention times, which may promote microbial regrowth and disinfection byproduct formation. Maintenance of adequate pressure can provide a barrier against contaminant intrusion, but excessive water pressure, including transients, can lead to pipe breaks. In fact, drinking water infrastructure in the United States is in serious need of investment, including the replacement of lead-lined pipes or connections that are found in many households.

It should be noted that there are differences in drinking water costs between Europe and the United States. Water prices in some western European countries are on average two to three times higher than in the United States (*14*). It is clear that pricing

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ILLUSTRATION: P. HUEY/SCIENCE

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for potable water also needs to be evaluated to determine how much should be spent to ensure microbiological safety and integrity of the distribution system.

To understand the long-term properties of water distribution systems, comparative data are needed on water quality, disease outbreaks, and distribution system failures from all approaches used to produce potable water. The water microbiome in distribution pipes and the definition of microbiologically safe water should be further investigated. In addition, improved monitoring and emerging sensor technology can provide warnings and alerts, helping to determine when to restore and protect extensive pipe assets. In the case of green water infrastructure, which includes water recycling, rainwater harvesting, and solar water heating, multiple barriers will be necessary to prevent opportunistic pathogens such as *Legionella*, which is higher in buildings with green water designs and longer water residence times (*15*). But the European evidence to date suggests that safe water can indeed be delivered without a disinfectant residual, as long as there are multiple barriers in operation. ■

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WATER

Saving freshwater from salts

Ion-specific standards are needed to protect biodiversity

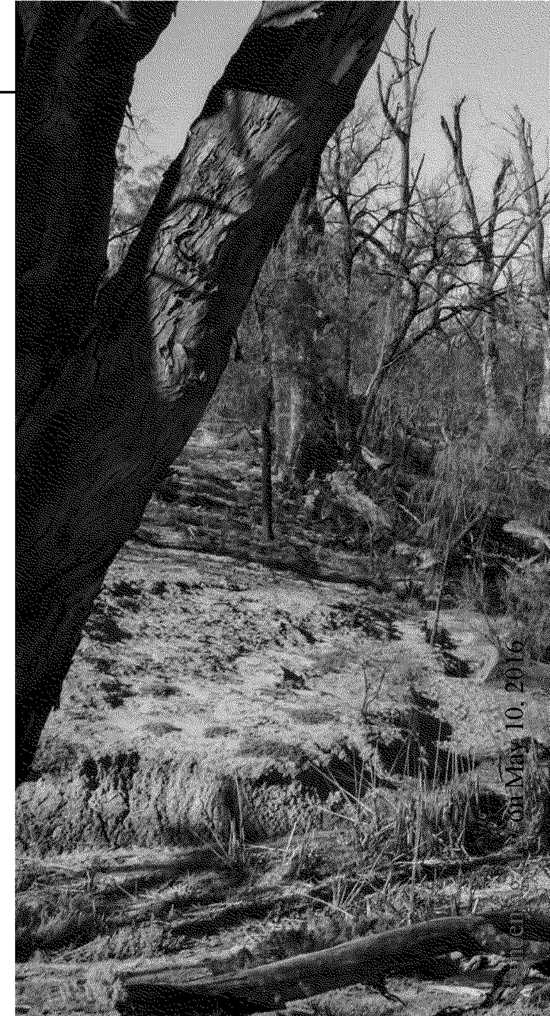
By **M. Cañedo-Argüelles,[1,2] C. P. Hawkins,[3] B. J. Kefford,[4] R. B. Schäfer,[5] B. J. Dyack,[4] S. Brucet,[6,1] D. Buchwalter,[7] J. Dunlop,[8] O. Frör,[5] J. Lazorchak,[9] E. Coring,[10] H. R. Fernandez,[11] W. Goodfellow,[12] A. L. González Achem,[11] S. Hatfield-Dodds,[13] B. K. Karimov,[14] P. Mensah,[15] J. R. Olson,[16] C. Piscart,[17] N. Prat,[2] S. Ponsá,[1] C.-J. Schulz,[18] A. J. Timpano[19]**

Many human activities—like agriculture and resource extraction—are increasing the total concentration of dissolved inorganic salts (i.e., salinity) in freshwaters. Increasing salinity can have adverse effects on human health (*1*); increase the costs of water treatment for human consumption; and damage infrastructure [e.g., amounting to $700 million per year in the Border Rivers catchment, Australia (*2*)]. It can also reduce freshwater biodiversity (*3*); alter ecosystem functions (*4*); and affect economic well-being by altering ecosystem goods and services (e.g., fisheries collapse). Yet water-quality legislation and regulations that target salinity typically focus on drinking water and irrigation water, which does not automatically protect biodiversity.

POLICY

For example, specific electrical conductivities (a proxy for salinity) of 2 mS/cm can be acceptable for drinking and irrigation but could extirpate many freshwater insect species (*3*). We argue that salinity standards for specific ions and ion mixtures, not just for total salinity, should be developed and legally enforced to protect freshwater life and ecosystem services. We identify barriers to setting such standards and recommend management guidelines.

Attempts to regulate salinization on the basis of ecological criteria can be found in the United States and Australia, where total salinity recommendations have been made (*5*, *6*). Even these criteria are insufficient to protect freshwater life, because waters with the same total amount of salts but different ionic composition can have markedly different effects on freshwater fauna (*7*).



Canada and the United States are the only countries in the world that identify concentrations of a specific ion (chloride) above which freshwater life will be harmed (*6*, *8*). Globally, concentrations of other ions (e.g., Mg^{2+}, HCO_3^-) remain free from regulation in spite of their potential toxicity (*9*).

The situation will likely worsen in the future, because predicted increase in demand for freshwater will reduce the capacity of surface waters to dilute salts, and increasing resource extraction and other human activities (*10*) will generate additional saline effluents and runoff. Climate change will likely exacerbate salinization by causing seawater intrusion in coastal freshwaters, increasing evaporation, and reducing precipitation in some regions (*11*).

SETTING STANDARDS. Scientific understanding of mechanisms by which increasing salinization damages freshwater ecosystems is in its infancy, which makes it challenging to develop and implement standards protective of freshwater life. Technical challenges are exacerbated by the fact that salinization risks perceived by the public and policy-makers may be much lower than those identified by scientists. In addition, although scientific input has been

PHOTO: © KERRY WHITWORTH/ALAMY STOCK PHOTO

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How do you like your tap water?
Fernando Rosario-Ortiz, Joan Rose, Vanessa Speight, Urs von Gunten and Jerald Schnoor (February 25, 2016)
Science **351** (6276), 912-914. [doi: 10.1126/science.aaf0953]

Editor's Summary

TIME April 11, 2016

How to Finally End Lead Poisoning in America

Bill Pugliano—Getty ImagesNew water pipes awaiting installation are shown along the route of a national mile-long march, which was held to highlight the push for clean water in Flint, Mich., on Feb. 19, 2016.

Philip Landrigan, MD, MSc, is a pediatrician and Dean for Global Health in the Icahn School of Medicine at Mount Sinai. David Bellinger, PhD, MSc, is a Professor of Neurology at Harvard Medical School and Boston Children's Hospital.

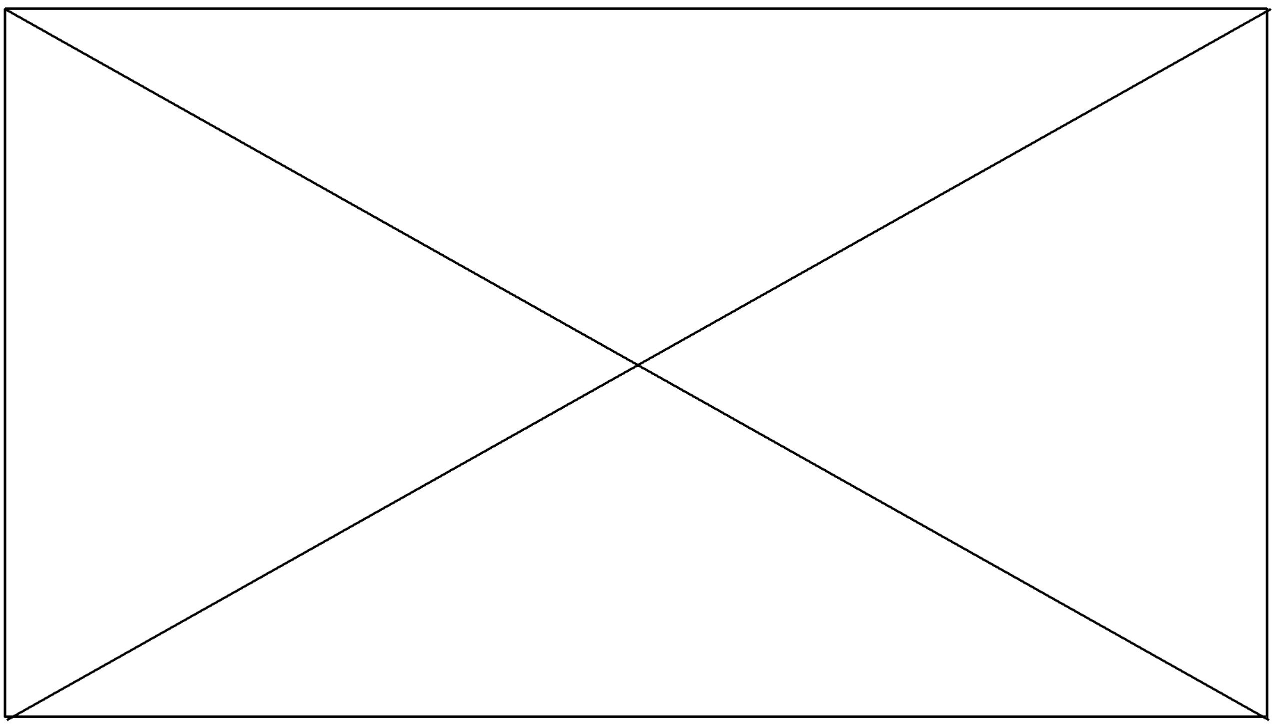
We must stop using children like canaries in a coal mine

Lead is a devastating poison. It damages children's brains, erodes intelligence, diminishes creativity and the ability to weigh consequences and make good decisions, impairs language skills, shortens attention span, and predisposes to hyperactive and aggressive behavior. Lead exposure in early childhood is linked to later increased risk for dyslexia and school failure. When lead exposure is widespread, it can undermine the economic productivity and sustainability of entire societies.

Lead is a silent poison. In most children, lead wreaks its havoc in the absence of any obvious signs or symptoms. Infants in the womb and children under the age of 5 are the most vulnerable. Research has shown that higher levels of exposure are the most dangerous, but that no level of lead is safe.

Lead was everywhere in 20th-century America. It was marketed aggressively by the lead industry and used widely in paint, gasoline and water pipes. At peak use in the early 1970s, more than 100,000 tons was added to gasoline each year to boost octane and enhance engine performance. This lead was released to the environment via automotive exhaust. It contaminated air, water and soil. And it got into the bodies of Americans of all ages, especially small children.

The tide began to turn against lead in the 1970s. Two key events were the discovery by Herbert Needleman and others that lead could cause silent brain injury, a finding that was savagely contested by the lead industry, and the realization that lead in gasoline could destroy the platinum-containing catalytic converters mandated on new cars under the Clean Air Act. Lead was removed from gasoline beginning in 1976, from house paint in 1978 and from drinking water pipes and solder in 1986. Average blood lead levels in children under 5 in the U.S. fell from 17 micrograms per deciliter in 1976 to 4 micrograms in the early 1990s, a decline of more than 75%, and have continued to fall.



But as we have seen in Flint, Mich., lead exposure is still epidemic in America. According to the Centers for Disease Control and Prevention, an estimated 535,000 children under the age of 5 still have elevated blood levels with silent poisoning. Approximately 20 million older American homes still contain lead paint, and approximately 10 million homes have lead water pipes. And as the horrific and entirely avoidable events in Flint so painfully demonstrate, the burden of lead often falls most heavily upon the poorest and most vulnerable among us.

To go the last mile and finally end lead poisoning in this country, we need to put in place a comprehensive three-point program:

1. Map the sources of lead.

In this era of big data when we can monitor billions of telephone conversations and visualize traces of water on Pluto, it is incomprehensible that we do not have a fine-grained national map of the sources of lead in America. CDC, the Department of Housing and Urban Development, and state and city health departments need to be given the resources they need to enable them to rapidly and comprehensively map lead sources block-by-block across the U.S.

Miners once used canaries to warn them of dangerously low oxygen levels. We seem to use children in the same way to warn us of lead. We wait for a child to become poisoned before we investigate the source of exposure. Given the limited options for treating children with lead poisoning, this is poor public health and bad medicine. We need to identify lead hazards before they harm children.

2. Get the lead out.

Once lead sources have been identified, they need to be contained. This will require removing lead paint from homes, replacing lead pipes and cleaning up contaminated soils. These actions are highly cost-effective because they prevent disease and lifelong disability not only in today's children, but in all future generations.

To build a national workforce for lead removal, green-jobs partnerships can be built between city governments and major unions to establish new vocational training programs that will prepare young men and women from urban communities to safely remediate lead. These programs will provide a portal to middle-class employment, increase the number of available housing units in inner cities and help lift entire neighborhoods out of poverty.

3. Make sure there is no new lead.

Despite the removal of lead from paint, pipes and gasoline, global lead production has remained steady. The major driver is the need for vast quantities of new lead in battery production. This is a dangerous trend that needs to be halted. It is time to eliminate all non-essential uses of lead. Replacement of the lead-acid battery by new lead-free technology is long overdue. Both to protect our children's health and to build a clean energy future, we need clean power sources for the 21st century.

Now is the time to end the profound immorality of lead poisoning in America. We have the science. We know how to do the job. What we need is leadership, courage and political will.

Federal Water Regulation

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Revised 5/13/16 - watch for updates

MICHIGAN STATE UNIVERSITY

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Water federalism and regulation in the U.S.

	Water quality	Water quantity	Water funding	Water prices
Federal	**Congress and EPA**	Court review as applicable	Congress and EPA	Judicial review
Interstate	Basin commissions	Basin commissions	*n/a*	*n/a*
States	**Primacy agencies (health & environmental)**	Resource agencies	Revolving loan funds (SRF)	PUCs and/or judicial review
Substate	Management districts (varies)	Management districts (varies)	*n/a*	*n/a*
Local	**Local health departments**	Local zoning and fire officials (pressure)	Local financing (bonds)	Municipal and other local boards

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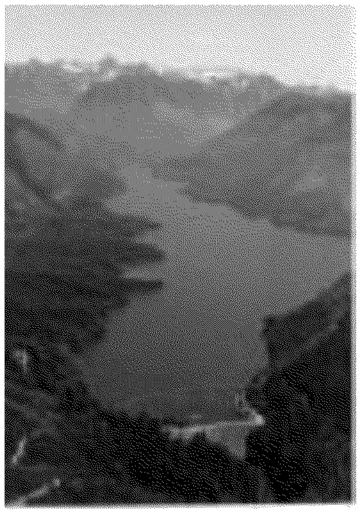
Federal water-quality legislation and goals

Clean Water Act
To achieve "fishable and swimmable waters" through pollution control, wastewater treatment, and stormwater management



Safe Drinking Water Act
To achieve a level of drinking water quality as close as feasible to that for which there are no known or anticipated adverse impacts to human health, including an adequate margin of safety

Clean Water Act (1972)

- "The Clean Water Act (CWA) establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters.
- The basis of the CWA was enacted in 1948 and was called the Federal Water Pollution Control Act, but the Act was significantly reorganized and expanded in 1972.
- "Clean Water Act" became the Act's common name with amendments in 1972.
- Under the CWA, EPA has implemented pollution control programs such as setting wastewater standards for industry. We have also set water quality standards for all contaminants in surface waters.
- The CWA made it unlawful to discharge any pollutant from a point source into navigable waters, unless a permit was obtained. EPA's National Pollutant Discharge Elimination System (NPDES) permit program controls discharges. Point sources are discrete conveyances such as pipes or man-made ditches.
- Individual homes that are connected to a municipal system, use a septic system, or do not have a surface discharge do not need an NPDES permit; however, industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters" (http://www2.epa.gov/laws-regulations/summary-clean-water-act)

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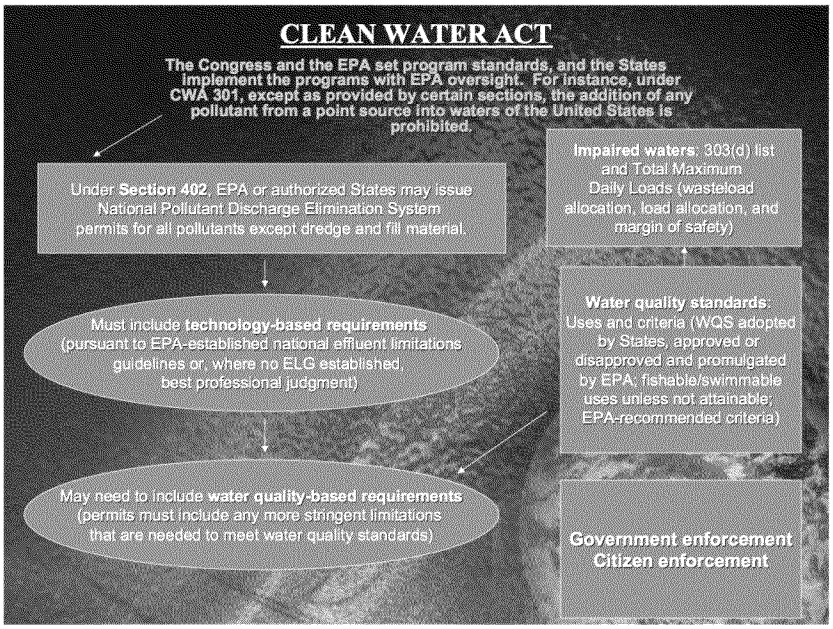
Clean Water Act summary



Clean Water Rule (2015, currently under judicial stay)

- Jointly developed by the US EPA and US Army Corps of Engineers
  - Thirteen states are exempt: Alaska, Arizona, Arkansas, Colorado, Idaho, Missouri, Montana, Nebraska, Nevada, New Mexico, North Dakota, South Dakota and Wyoming.
- "The rule ensures that waters protected under the Clean Water Act are more precisely defined and predictably determined, making permitting less costly, easier, and faster for businesses and industry. The rule is grounded in law and the latest science, and is shaped by public input. The rule does not create any new permitting requirements for agriculture and maintains all previous exemptions and exclusions."
- According to the EPA and Army, the rule:
  - Clearly defines and protects tributaries that impact the health of downstream waters
  - Provides certainty in how far safeguards extend to nearby waters
  - Protects the nation's regional water treasures
  - Focuses on streams, not ditches
  - Maintains the status of waters within Municipal Separate Storm Sewer Systems
  - Reduces the use of case-specific analysis of waters

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Early history of drinking water and public health

State and county programs emerged

Large-scale chlorination

1906

Early 1900s

1908

Filtration in Philadelphia

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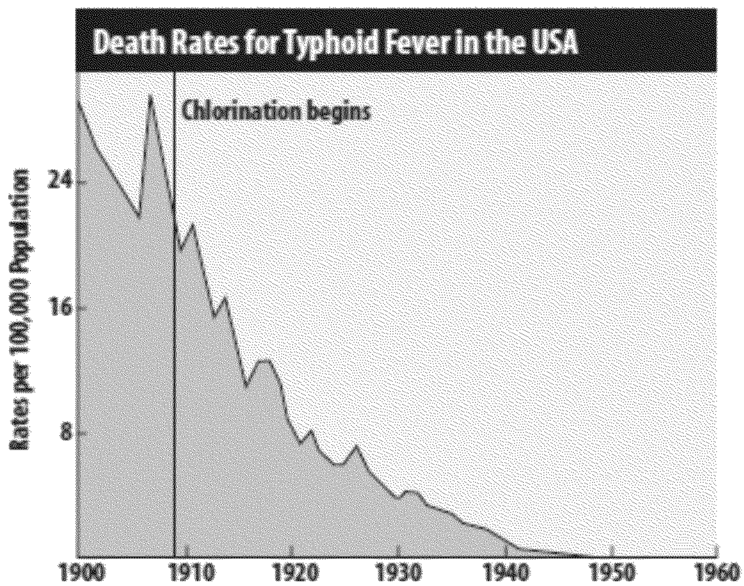
Early success in drinking-water protection



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Early state regulation (Montana)

Montana public water supply statute

Statute weakened

Statute revised to original form

1907

1911

1915

Emerging federal role and the USEPA

- Public Health Service (1912)
  - Formerly the Public Health and Marine Hospital Service
  - Broadened power to investigate human diseases (such as tuberculosis, hookworm, malaria, and leprosy), sanitation, water supplies, and sewerage disposal
- Indian Health Service (1956)
  - Water and wastewater facilities
- Federal statutes that lacked enforcement authority
  - Water Pollution Control Act of 1948
  - Federal Water Pollution Control Act of 1956
  - Water Quality Act of 1965
- U.S. Environmental Protection Agency
  - Established under the Nixon administration on December 2, 1970
  - Consolidated under one agency federal research, monitoring, standard-setting and enforcement activities to ensure environmental protection

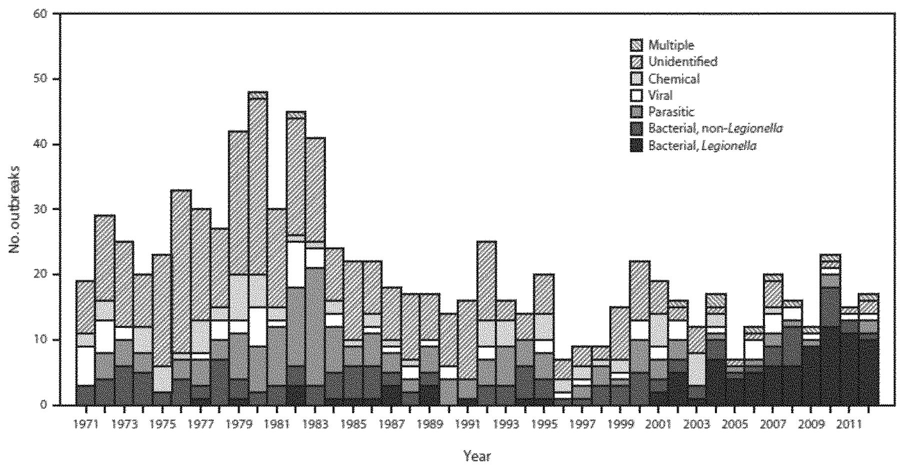
Evolution of drinking water regulation

- USPHS survey of community water systems (1969)
- Many especially smaller systems were not complying with PHS standards
- Organic chemicals found in New Orleans finished water (1972)
- Epidemiology study linking drinking water to cancer in New Orleans (1974)
- Reauthorization linked to public health crises (giardia, cryptosporidium)

Continuing challenge of water contamination (CDC)

- Opportunistic pathogens (OPs) in aging and sluggish distribution systems and premise plumbing are a growing concern (e.g., Legionellosis, Pontiac fever)

FIGURE. Etiology of 885 drinking water–associated outbreaks, by year — United States, 1971–2012*



* Legionellosis outbreaks were first reported to CDC Waterborne Disease and Outbreak Surveillance System in 2001; Legionellosis outbreaks before 2001 were added retrospectively during the 2007–2008 reporting period.

Alternate Text: The figure above is a bar chart showing the etiology of 885 drinking water-associated outbreaks, by year, in the United States during 1971-2012.

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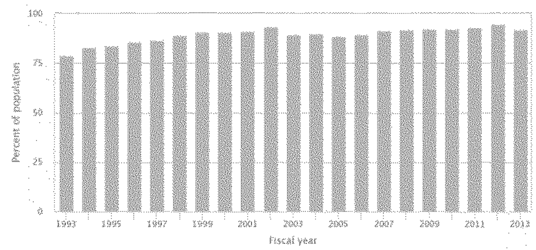
Population served with no reported violations

Exhibit 1. U.S. population served by community water systems with no reported violations of EPA health-based standards, fiscal years 1993-2013



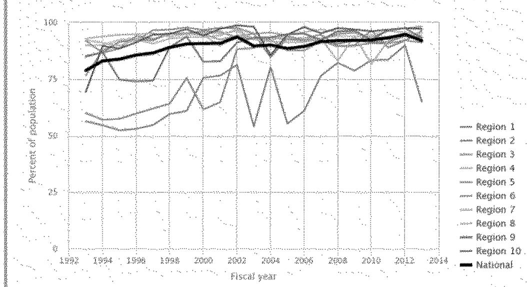
Coverage: U.S. residents served by community water systems (CWS) (approximately 95% of the total U.S. population).

Several new standards went into effect during the time period shown.

Information on the statistical significance of the trend in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2014

Exhibit 2. U.S. population served by community water systems with no reported violations of EPA health-based standards, by EPA Region, fiscal years 1993-2013



Coverage: U.S. residents served by community water systems (CWS) (approximately 95% of the total U.S. population).

Based on reported violations of the standards in effect in any given year.

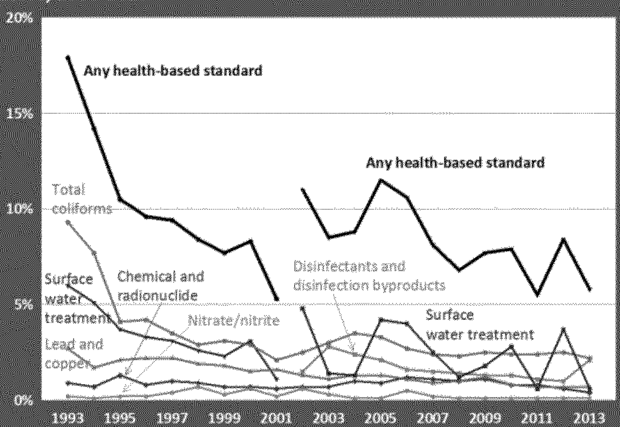
Information on the statistical significance of the trends in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2014

Exposure of children to noncompliant water

Indicator E7

Estimated percentage of children ages 0 to 17 years served by community water systems that did not meet all applicable health-based drinking water standards, 1993-2013



Data: U.S. Environmental Protection Agency, Office of Water, Safe Drinking Water Information System, Federal Version

Note: Breaks in lines for "Any health-based standard" and "Surface water treatment" reflect substantial regulatory changes implemented in 2002.

America's Children and the Environment, Third Edition, Updated October 2015

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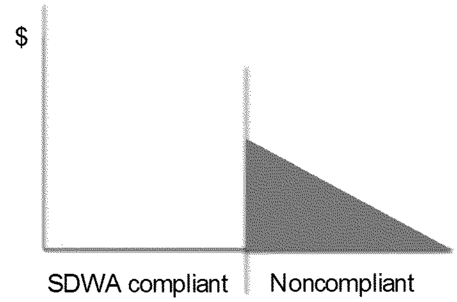
Drinking water regulation

- Customers expect water to be safe and "wholesome" – *regardless of regulation*
- Equal protection under uniform preventive and protective standards informed by public-health and environmental science
  - Multiple barriers to contamination and a professionalized culture of compliance
  - Variances and exemptions are narrow, uncommon (MI reported none in 2014)
- While there is no "right" to drinking water, there is an obligation of all water systems to deliver compliant water
  - If standards are sound, compliant water should be safe and customers should be confident
  - Compliance is not optional or discretionary, regardless of structural or fiscal conditions
  - Other dimensions (including ownership, finances, and rates) are discretionary



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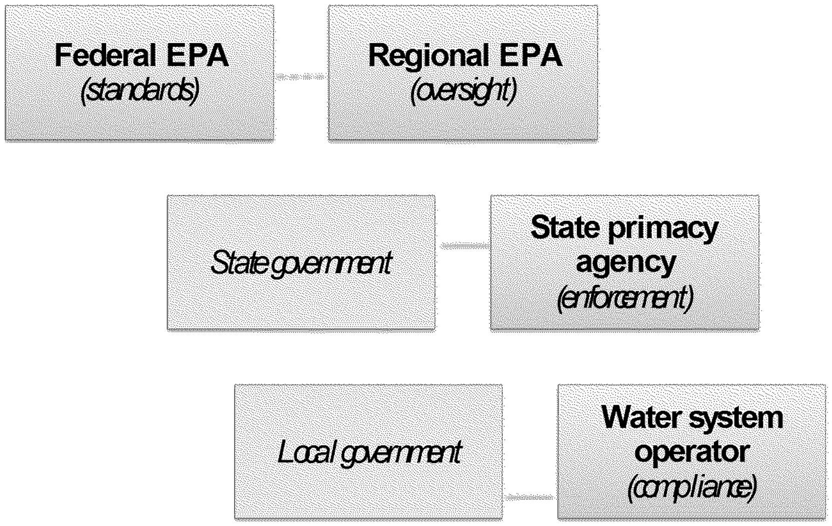
Safe Drinking Water Act (SDWA) and core principles

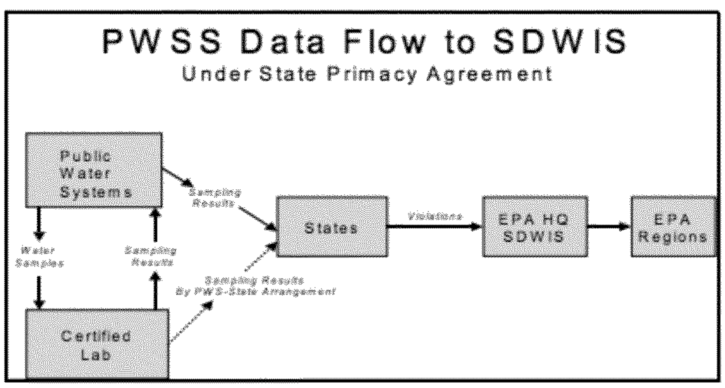
- SDWA is democratically established federal law (1974, 1986, 1996)
- Safe Drinking Water Act (SDWA) of 1974
  - Authorizes EPA to promulgate National Primary Drinking Water Regulations
  - Established the public water system supervision (PWSS), underground injection control (UIC), and sole source aquifer (SSA) program
  - Established the 15-member National Drinking Water Advisory Council (NDWAC) to support EPA with regard to the drinking water program
  - Provided for state primacy in implementation and enforcement
  - State laws may mirror federal law and may be more but not less stringent
- Fundamental goal of water quality regulation
  - "Each maximum contaminant level goal established under [the Act] shall be set at the level at which no known or anticipated adverse effects on the health of persons occur and which allows an adequate margin of safety."
  - Aesthetic issues are not federally regulated but may indicate other problems

Regulatory chain of command



Violation reporting

Figure 5: SDWIS Data Flow



Source: *EPA Office of Water*

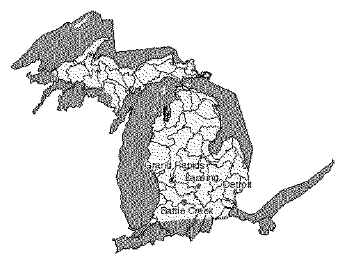
EPA emergency powers (§1431)

(a) Actions authorized against imminent and substantial endangerment to health. Notwithstanding any other provision of this subchapter the Administrator, upon receipt of information that a contaminant which is present in or is likely to enter a public water system or an underground source of drinking water, or that there is a threatened or potential terrorist attack (or other intentional act designed to disrupt the provision of safe drinking water or to impact adversely the safety of drinking water supplied to communities and individuals), which may present an imminent and substantial endangerment to the health of persons, and that appropriate State and local authorities have not acted to protect the health of such persons, may take such actions as he may deem necessary in order to protect the health of such persons. To the extent he determines it to be practicable in light of such imminent endangerment, he shall consult with the State and local authorities in order to confirm the correctness of the information on which action proposed to be taken under this subsection is based and to ascertain the action which such authorities are or will be taking. The action which the Administrator may take may include (but shall not be limited to) (1) issuing such orders as may be necessary to protect the health of persons who are or may be users of such system (including travelers), including orders requiring the provision of alternative water supplies by persons who caused or contributed to the endangerment, and (2) commencing a civil action for appropriate relief, including a restraining order or permanent or temporary injunction.

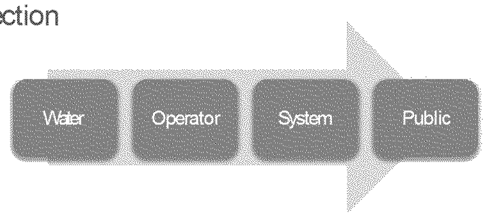
(b) Penalties for violations; separate offenses. Any person who violates or fails or refuses to comply with any order issued by the Administrator under subsection (a)(1) of this section may, in an action brought in the appropriate United States district court to enforce such order, be subject to a civil penalty of not to exceed $15,000 for each day in which such violation occurs or failure to comply continues.

Multiple barriers and standards

- States and EPA had different approaches
  - State approaches came from public health programs
- State multiple-barrier approach
  - Source selection and protection, treatment, and distribution
  - Plans and specifications for water systems
  - Sanitary surveys and training
- EPA standards approach
  - Establish standards
  - Monitor for compliance with standards
  - Enforce against those who do not comply
- U.S. regulatory regime today
  - Active identification of jurisdictional systems
  - Robust regulatory standards for drinking water quality
  - A complementary incentive-based suite of protection programs based on multiple barriers
    - Source water assessment and protection
    - Qualified water treatment operators
    - Integrity of water distribution systems
    - Informed public (notice, CCR)



"Surf your watershed"



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1976 Public Water System Supervision (PWSS)

- Since 1976 EPA has annually received a Congressional appropriation under §1443(a) of the SDWA to assist states, territories, and tribes in carrying out their PWSS programs
- Entities that have been delegated primary enforcement responsibility (primacy) by EPA for the PWSS program are eligible to receive grants
- PWSS evolved to support standard-setting, monitoring, enforcement, preventive action
- Key activities carried out under a PWSS program include:
  - Developing and maintaining state drinking water regulations;
  - Developing and maintaining an inventory of public water systems throughout the state;
  - Developing and maintaining a database to hold compliance information on public water systems;
  - Conducting sanitary surveys of public water systems;
  - Reviewing public water system plans and specifications;
  - Providing technical assistance to managers and operators of public water systems;
  - Carrying out a program to ensure that the public water systems regularly inform their consumers about the quality of the water that they are providing;
  - Certifying laboratories that can perform the analysis of drinking water that will be used to determine compliance with the regulations; and
  - Carrying out an enforcement program to ensure that the public water systems comply with all of the state's requirements.

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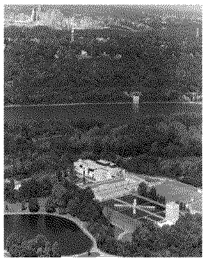
1986 SDWA Amendments



- Prescriptive approach
- Tight deadlines
- Eighty-three (83) contaminants in three years
- Additional 25 contaminants every 5 years
- Added ground water protection programs (wellhead protection)
- Creation of the NTNC category of water system
- Organic chemicals (monitoring and detection, risk communication)
- Surface water treatment rule
- Ground water under the direct influence (of surface water) – GWUDI
- Public notification
- More stringent coliform monitoring requirements
- Lead and copper rule and corrosion control

1996 SDWA Amendments

- Reflected federal incorporation of preventive programs
  - Some states had focused on multiple barrier protection since the early 1900's
  - 1974 and 1986 Amendments focused on regulation, monitoring, and enforcement
  - With the 1996 Amendments, Congress recognized that the public health protection objectives of SDWA required a broader set of tools to accomplish goals
- Drinking Water State Revolving Fund (DWSRF)
  - National set-aside for monitoring of unregulated contaminants.
  - State set-asides to fund source water protection, operator certification, and capacity development
- Capacity development to proactively address system compliance concerns
  - New and existing systems
  - Funding incentives under the DWSRF

EPA classification of public water systems

Public water systems (public or private) subject to EPA jurisdiction

Community water systems

Noncommunity water systems

Transient population

Nontransient population

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Types of public water systems (continued)

§ **Public water system**

- Provides water for human consumption through pipes or other constructed conveyances to at least 15 service connections or serves an average of at least 25 people for at least 60 days a year
- May be publicly or privately owned

§ **Community water system**

- Serves the same people all year
  - Public: mostly municipalities but also governmental districts and authorities
  - Private: for-profit; nonprofit; ancillary, including homeowners' associations

§ **Non-transient non-community system**

- Serves same 25 people at least 6 months/year (but not year-round)
- Schools, factories, office buildings, hospitals.

§ **Transient non-community system**

- Serves different people
- Gas stations, parks, resorts, campgrounds, restaurants, and motels

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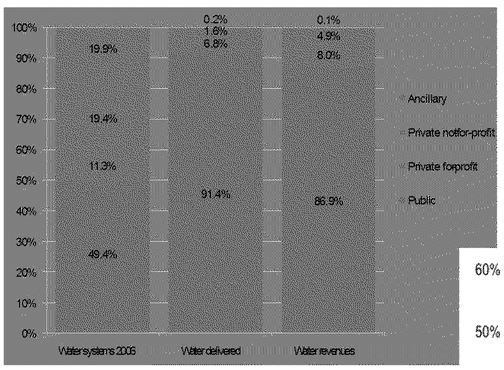
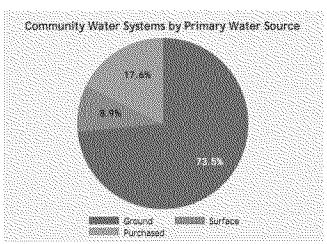
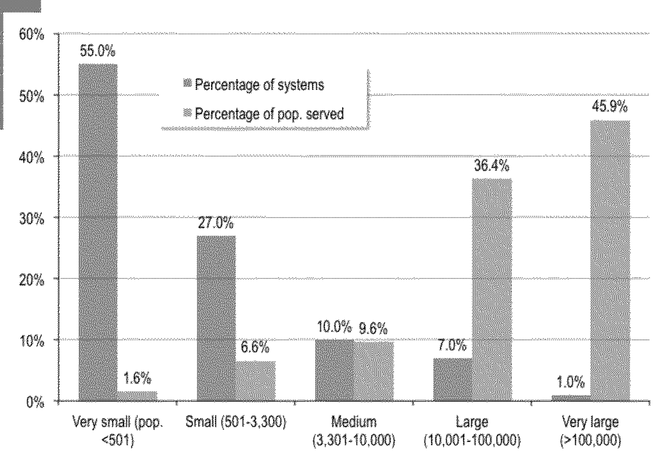
U.S. industry structure (2011): 51,356 community water systems served almost 300 mil. people







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EPA regulations

§ National Primary Drinking Water Regulation – legally enforceable standards
- Limits levels of specific contaminants that can adversely affect public health
- Maximum Contaminant Level (MCL) or Treatment Technique (TT)

§ National Secondary Drinking Water Regulation – non-enforceable guidelines
- Covers contaminants that may cause cosmetic or aesthetic effects

§ Maximum Contaminant Level Goal (MCLG) – non-enforceable goals
- § 1412(b)(4)(A): "…level at which no known or anticipated adverse effects…occur and which allows for an adequate margin of safety."

§ Maximum Contaminant Level (MCL) – enforceable
- § 1412(b)(4)(B): "level… as close to the maximum contaminant level goal as is feasible."

§ Treatment Technique – enforceable based
- § 1412(b)(7): "…in lieu of establishing a maximum contaminant level, if…it is not economically or technologically feasible to ascertain the level of the contaminant."

From risk to rule

Hazard identification (health effects)

▸ Dose-response assessment

▸ Exposure assessment

▸ Risk characterization

▸ Regulatory alternatives development

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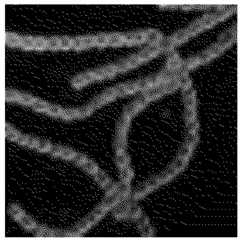
Regulatory framework and rules

- Microbial contaminants
  - Bacteria, viruses, and protozoa (e.g., Cryptosporidium, Giardia, especially from fecal sources)
    - Aircraft drinking water
    - Ground water
    - Surface water treatment
    - Total coliform rule (revised rules)
- Chemical, metal, and radiological contaminants
  - Toxins, neurotoxins, endocrine disrupters, etc.
  - Naturally occurring chemicals
    - Arsenic
    - Lead and copper
    - Radionuclides
  - Manmade chemicals
    - Chlordane and dioxin
    - Volatile and synthetic organic chemicals (VOCs and SOCs)
    - Inorganic chemicals (IOCs)
- Disinfectants and disinfection byproducts (Stage 1 and 2)
  - Based on increased risks of cancer and reproductive and developmental effects
  - Trihalomethanes and haloacetic acids
- Contaminant candidate listing (emerging threats)
  - Chemicals used in commerce, pesticides, biological toxins, disinfection byproducts, pharmaceuticals, and waterborne pathogens
  - Formal determination of need for regulation every five years



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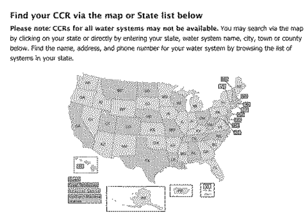
Regulatory framework and rules (continued)

- Monitoring and reporting
  - Regulated and unregulated contaminants
- Public information and notice
  - Consumer confidence report rule
  - Public notification rule
- System capacity and planning
  - Operator certification guidelines
  - Capacity development programs for new and existing systems
  - Voluntary conservation planning guidelines
  - Information and guidance to states and suystems (affordability, cross-connection control)
- Funding and incentives
  - Drinking Water State Revolving Loan Fund (DWSRF)
  - Restructuring provisions related to funding, capacity, and variances
- Variances and exemptions
  - For systems unable to comply with a NPDWR due to their source water quality when no feasible alternate source of water is available
  - For small systems serving 3,300 persons or fewer that cannot afford to comply with a NPDWR or systems serving up to 10,000 persons on a case-by-case basis)
  - No variances for microbial contaminants based on size
- Six-year regulatory review and emergency powers
  - Ensures that standards remain as protective as feasible by considering new health effects data that suggest the need for stronger standards as well as any advances in treatment technology
  - Federal government has emergency powers of intervention (§1431)



Contaminant evaluation

- Adverse health effects
  - Acute exposure from pathogens and nitrates (especially infants)
  - Chronic exposure over time
  - Exposure during critical periods of development
- Carcinogenicity
  - Category I compounds are carcinogens
  - Category II compounds exhibit carcinogenic & noncarcinogenic endpoints
  - Category III compounds are noncarcinogenic
- Sensitive sub-populations
  - Infants and children
  - Elderly people
  - Immuno-compromised individuals
  - Highly exposed individuals
- National Contaminant Occurrence Database
  - Contaminant occurrence data for finished, untreated, and source waters
  - Information is from SDWIS and NWIS

Key steps in developing drinking water regulations

- Evaluate contaminant occurrence and exposure
- Set the maximum contaminant level goal (MCLG)
- Develop standard (MCL) and (TT) alternatives
  - Evaluate the costs and benefits (quantifiable and unquantifiable) and uncertainties
  - Document support for the proposed or final rule in an Economic Analysis and other technical analyses (health criteria document; occurrence and exposure document; cost and technology document)
- Set the maximum contaminant level (MCL)
  - An MCL is an enforceable standard set as close to the MCLG as feasible
  - SDWA provides guidance on the meaning of feasible in §1412(b)(4)(E)
  - Requires a determination as to whether the benefits justify the costs
- Specify a treatment technique (TT)
  - Alternative to MCL when it is not economically & technologically feasible to ascertain the contaminant level
  - An enforceable standard involving a measurable procedure or level of technological performance
  - Exceeding an “action level” (AL) triggers treatment technique and notification
  - Includes:
    - Surface Water Treatment Rule (disinfection and filtration)
    - Lead and Copper Rule (MCLG = 0; no MCL; requires optimized corrosion control)
    - Acrylamide and Epichlorohydrin Rule (purity of treatment chemicals)
- Specify the best available technology (BAT) as appropriate

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Secondary standards

§ Nonmandatory guidelines to control aesthetic (taste and odor), cosmetic, and technical effects

Table of Secondary Drinking Water Standards

Contaminant	Secondary MCL	Noticeable Effects above the Secondary MCL
Aluminum	0.05 to 0.2 mg/L*	colored water
Chloride	250 mg/L	salty taste
Color	15 color units	visible tint
Copper	1.0 mg/L	metallic taste; blue-green staining
Corrosivity	Non-corrosive	metallic taste; corroded pipes/ fixtures staining
Fluoride	2.0 mg/L	tooth discoloration
Foaming agents	0.5 mg/L	frothy, cloudy; bitter taste; odor
Iron	0.3 mg/L	rusty color; sediment; metallic taste; reddish or orange staining
Manganese	0.05 mg/L	black to brown color; black staining; bitter metallic taste
Odor	3 TON (threshold odor number)	"rotten-egg", musty or chemical smell
pH	6.5 - 8.5	low pH: bitter metallic taste; corrosion high pH: slippery feel; soda taste; deposits
Silver	0.1 mg/L	skin discoloration; graying of the white part of the eye
Sulfate	250 mg/L	salty taste
Total Dissolved Solids (TDS)	500 mg/L	hardness; deposits; colored water; staining; salty taste
Zinc	5 mg/L	metallic taste

*mg/L is milligrams of substance per liter of water.

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Benefit and cost analysis

§ Prior to 1996, benefit-cost analysis informed decisions but was not incorporated into the rulemaking process

§ 1996 SDWA Amendments added §1412(b)(6)

- "... if the Administrator determines... that the benefits of a maximum contaminant level ... would not justify the costs of complying with the level, the Administrator may, after notice and opportunity for public comment, promulgate a maximum contaminant level that maximizes health risk reduction benefits at a cost that is justified by the benefits."

§ Regardless of whether it's an MCL or a treatment technique, the information gathering and analytical processes are similar

§ Cost of compliance

- Capital costs for installing treatment
- Operation and maintenance (O&M) costs for the treatment
- Monitoring and reporting costs
- Administrative costs to systems, States, and EPA

Quantifying benefits of reducing health risks

- Occurrence and exposure information
  - Reduced exposure
- Dose-response information
  - Deaths or disease avoided
- Monetization of "cases avoided"
- Monetary ($) value = benefits
- Nonquantifiable benefits must also be considered
  - Benefits of avoided health effects that can't be measured
  - Cost savings associated with the removal of other contaminants
  - Gaining economies of scale by merging with other water systems

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Consumer confidence reporting

Genesee County Water and Waste Services Detected Contaminants Tables

Regulated Contaminant	Test Date	Units	Health Goal MCLG	Allowed Level MCL	Highest Level Detected	Range of Detection	Violation yes/no	Major Sources in Drinking Water
Inorganic Chemicals - Annual Monitoring at Plant Finished Water Tap								
Fluoride	5/13/2013	ppm	4	4	0.55	n/a	No	Erosion of natural deposits; Water additive, which promotes strong teeth; Discharge from fertilizer and aluminum factories.
Nitrate	5/13/2013	ppm	10	10	0.32	n/a	No	Runoff from fertilizer use; Leaching from septic tanks, sewage; Erosion of natural deposits
Barium	6/9/2008	ppm	2	2	0.01	n/a	No	Discharge of drilling wastes; Discharge from metal refineries; Erosion of natural deposits.

Disinfectant By-Product Monitoring in Distribution System

Contaminant	Test Date	Units	Health Goal MCLG	Allowed Level MCL	LRAA	Range of Detection	Violation yes/no	Major Sources in Drinking Water
Total Trihalomethanes (TTHM)	2013	ppb	n/a	80	0.0438	0.0099 to 0.0438	No	By-product of drinking water chlorination
Haloacetic Acids (HAA5)	2013	ppb	n/a	60	0.025	0.006 to 0.025	No	By-product of drinking water disinfection
Disinfectant (Total Chlorine residual)	Jan-Dec 2013	ppm	MRDGL 4	MRDL 4	Highest RAA 1.33	0.5 to 1.33	No	Water additive used to control microbes

2013 Turbidity - Monitored every 4 hours at Plant Finished Water Tap

Highest Single Measurement Cannot exceed 1 NTU	Lowest Monthly % of Samples Meeting Turbidity Limit of 0.3 NTU (minimum 95%)	Violation yes/no	Major Sources in Drinking Water
0.26 NTU	100%	No	Soil Runoff

Turbidity is a measure of the cloudiness of water. We monitor it because it is a good indicator of the effectiveness of our filtration system.

2013 Microbiological Contaminants - Monthly Monitoring in Distribution System

Contaminant	MCLG	MCL	Number Detected	Violations yes/no	Major Sources of Contaminant
Total Coliform bacteria	0	Presence of Coliform bacteria >5% of monthly samples	none detected	No	Naturally present in the environment
E. coli or Fecal coliform bacteria	0	A routine sample and a repeat sample are total coliform positive, and one is also fecal or E. coli postitive	none detected	No	Human waste and animal fecal waste

2013 Special Monitoring

Sodium (ppm)	ppm	na	na	4.52	na	Erosion of natural deposits

Regulated Contaminant	Treatment Techniques	Running Annual Average	Monthly Ratio Range	Violation Yes/No	Typical Source of Contaminant
Total Organic Carbon (ppm)	The Total Organic Carbon (TOC) removal ratio is calculated as the ratio between the actual TOC removal and the TOC removal requirements. The TOC was measured each month and because the level was low, there is no requirement for TOC removal.				Erosion of natural deposits

Genesee County Lead and Copper Results

Contaminants	Test Date	Units	Number of Samples	Number of Samples Exceeding AL	Action Level AL	90th Percentile	Major Source in Drinking Water	Violations (Yes or No)
Lead	2011	ppb	14	0	15	0.001	Corrosion of Household Plumbing Erosion of natural deposits	NO
Copper	2011	ppb	14	0	1.3	0.04	Corrosion of Household Plumbing Erosion of natural deposits	NO

Enforcement action and public notice

STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
LANSING DISTRICT OFFICE

RICK SNYDER
GOVERNOR

DEQ

DAN WYANT
DIRECTOR

December 16, 2014

Mr. Brent Wright, Operation Supervisor
City Of Flint - DPW
Flint Water Plant
4500 North Dort Highway
Flint, MI 48505

WSSN: 02310

Dear Mr. Wright:

SUBJECT: Violation Notice – Maximum Contaminant Level for Total Trihalomethanes
Operational Evaluation – Total Trihalomethanes
4th Quarter 2014 Monitoring Period

The Department of Environmental Quality (DEQ), Office of Drinking Water and Municipal Assistance (ODWMA), records show that the City of Flint is in violation of the Safe Drinking Water Act,1976 PA 399, as amended (Act 399): R 325.10610, *Maximum contaminant levels* (MCL) *for disinfection byproducts*, of the 1979 Administrative Code.

In accordance with R.325.10610, *MCLs for disinfection byproducts*, of the 1979 Administrative Code, the MCL for disinfection byproduct total trihalomethanes (TTHM) is 0.080 milligrams per liter (mg/L) as a Locational Running Annual Average (LRAA) at each monitoring location. As listed in the table below, our records show that the City of Flint's highest TTHM locational running annual average (LRAA), based on the last three quarters, ending November 30, 2014, is 0.099 mg/l which exceeds the standard, and that two of the eight sample site locations exceed the standard of 0.080 mg/L.

Further, in accordance with R325.10719l, *Disinfection byproducts: operational evaluation levels*, of the 1979 Administrative Code, when an operational evaluation level (OEL) at a monitoring location for TTHM exceeds 0.080 mg/L, a supply shall conduct an operational evaluation and submit a written report of the evaluation to the department not later than 90 days after being notified of the analytical result that causes the supply to exceed the operational evaluation level. As listed in the table below, our records show that TTHM operational evaluation levels for the City of Flint exceed 0.080 mg/L at four of the City's eight sample site locations.

TTHM Results (mg/L)	5/21/14	8/21/14	11/20/14	LRAA	OEL
DBP1 McDonalds 3719 Davison	**0.162**	**0.145**	0.059	**0.092**	**0.106**
DBP2 Liquor Palace 3302 S. Dort Highway	**0.112**	**0.127**	0.033	0.068	0.076
DBP3 North Flint Auto 6204 N. Saginaw St.	**0.097**	**0.118**	0.041	0.064	0.074
DBP4 University Market 2501 Flushing Road	**0.106**	**0.196**	**0.094**	**0.099**	**0.122**
DBP5 Taco Bell 3606 Corunna Road	0.079	**0.181**	0.034	0.074	**0.082**
DBP6 Rite-Aid Pharmacy 5018 Clio Road	**0.086**	**0.144**	0.054	0.072	**0.085**
DBP7 Salem Housing 3216 MLK Boulevard	**0.082**	**0.112**	0.050	0.061	0.074
DBP8 BP Gas Station 822 S. Dort Highway	0.075	**0.112**	0.036	0.056	0.065

Our investigation consisted of a review of ODWMA files for laboratory reports received for compliance monitoring. Our investigation is considered complete. This violation began on December 1, 2014, and will continue until TTHM LRAA is below the MCL at all sample sites.

We acknowledge and appreciate the city's cooperation with our recommendation to preemptively conduct an Operational Evaluation following the City's second quarterly round of monitoring in August. That Operational Evaluation report has identified possible causes and corrective measures for the elevated TTHM levels which we encourage the City continue implementing. These modifications have likely contributed in part to the reduction in TTHM levels reported in the most recent quarter, and suggest the City may be able to achieve compliance with the TTHM standard.

Our office is continuing to review the Operational Evaluation report that was submitted on December 1, 2014, and will provide the City and their consultant comments as needed to help address this MCL violation.

Water systems that exceed the OEL must complete and submit an Operational Evaluation in accordance with Administrative Rule 719l (R325.10719l) within 90 days of being notified of the violation. **An updated Operational Evaluation report, which incorporates the most recent sample results, must now be completed and received by our office by no later than March 1, 2015.**

If you have any other factual information you would like us to consider regarding the violation identified in this Violation Notice (VN), please provide them in a written response by January 16, 2015.

Administrative rule R 325.10403 of Act 399 requires that suppliers provide public notice (PN) as soon as practical, but no later than thirty (30) days after the supplier learns of this type of violation, by mail or direct delivery and by any other means reasonably calculated to reach customers not normally reached by mail. Enclosed is a sample PN

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
OFFICE OF DRINKING WATER AND MUNICIPAL ASSISTANCE

DEQ

LEAD AND COPPER REPORT AND
CONSUMER NOTICE OF LEAD RESULT
CERTIFICATE FOR COMMUNITY WATER SUPPLY

Issued under authority of 1976 PA 399, MCL 325.1001 et al., and Administrative Rules, as amended.
Failure to submit this information is a violation of Act 399 and may subject the water supply to enforcement penalties.

Administrative Rule R.325.10710d requires water supplies to report lead and copper monitoring information within 10 days after the end of the monitoring period. This form may be used to meet this requirement. Submit the information to the appropriate Department of Environmental Quality (DEQ) district office. For district office addresses, visit www.michigan.gov/deq and click on Locations.

1. Water Supply Name: City of Flint Water Plant
2. County: Genesee 3. WSSN: 2310
4. Population: 99,763 5. Monitoring Period: From: 1/1/15 To: 6/30/15
6. Minimum # of Samples Required: 60 7. # of Samples Taken: 69
8. Name of Certified Laboratory: DEQ Drinking Water Laboratory

9. SAMPLE CRITERIA:

Yes	No	Explain No responses in Comments block.	
[ ]	[X]	a. Are the same sampling points used as in the previous monitoring period?	
[ ]	[X]	b. Are all samples from Tier 1 sites?	For more information see *instructions* paragraph 11, subparagraph "Sample Category."
[X]	[ ]	c. Are all samples from Tier 1, 2, or 3 sites giving Tier 1 priority?	
[X]	[ ]	d. If no Tier 1, 2, or 3 sites are available, do all sites have plumbing materials commonly found at other locations in the system?	
[X]	[ ]	e. Is the minimum number of lead service line samples taken (when applicable)?	

Comments: Revised report after conference call with DEQ staff. Two samples were removed from list for not meeting sample criteria, and due to population the number of samples required was reduced to 60.

10. NAME:

Name: Michael Glasgow

Title: Utilities Administrator Phone: 810-766-7135 Date: 6/20/2015

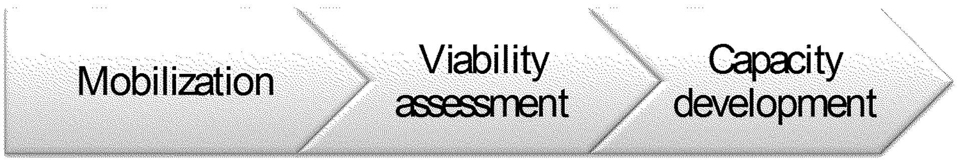
1996 SDWA and restructuring: key provisions

- Capacity assurance for water systems—technical, managerial, financial (§1420)
  - Demanding state requirements (e.g., plans) have slowed formation of new systems
  - Capacity development strategies for existing systems
- Consolidation Incentive - Enforcement (§1455)
- Variances (§1415)
- Exemptions (§1416)
- State Revolving Fund (§1452)
- Research (§1420)
- Despite some focus on the structural character of the industry (community v. noncommunity, transience, and size) the federal government is indifferent about ownership (public. v. private)

IPUMSU

Capacity development and SRF incentives

- From “mobilization,” to “viability assessment,” to “capacity development”
- Goals of capacity development
  - To ensure consistent compliance with drinking water standards
  - To enhance water system performance
  - To promote continuous improvement
- No State Revolving Fund (SRF) loans to systems that do not have adequate capacity, unless funding will improve capacity
  - Ensures that public funds are well invested and help leverage capacity development



IPUMSU

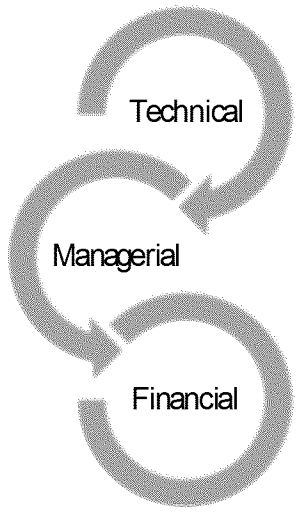
Capacity development requirements

- Requirements for new water systems
  - States must ensure that all new community and nontransient noncommunity water systems demonstrate technical, managerial & financial capacity for compliance prior to start-up
  - Various state agencies may review applications
- Requirements for existing water systems
  - States must develop and implement a strategy to assist exisitng public water systems in acquiring and maintaining technical, managerial, and financial capacity, including
    - Methods or criteria to identify systems and prioritize need
    - Factors that encourage or impede capacity development
    - Authority and resources to:
      - Provide assistance for compliance
      - Encourage partnerships
      - Promote training and certification

IPUMSU

What is capacity?

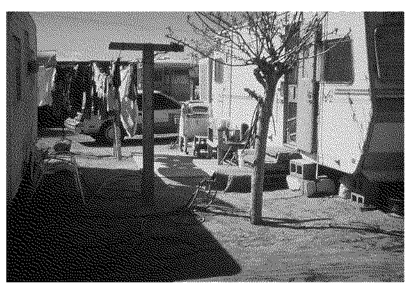
- Water system capacity is the ability to plan for, achieve, and maintain compliance with applicable drinking water standards
- As noted, capacity development also extends beyond compliance
- For a system to have “capacity” it must have “adequate” capability in three areas--technical, managerial, and financial
- Each element is necessary but not sufficient.
- Many water system functions involve more than one capacity element
- Monitoring, assessment, and planning can address all three elements of capacity



IPUMSU

Capacity examples

System has capacity	System lacks capacity
Files complete and timely reports	Does not answer the phone or respond to contact
Follows standard operating procedures	Has an owners who is absent an uninvolved
Demonstrates pride of ownership	Does not maintain financial or operational records
Conducts effective board meetings	Cannot complete timely reports
Has a computer and software	Does not review or revise rates
Attends professional meetings	Cannot provide consistent service quality
Communicates well with customers	Experiences high water losses
Meters and bills for cost of service	Has a crumbling distribution infrastructure



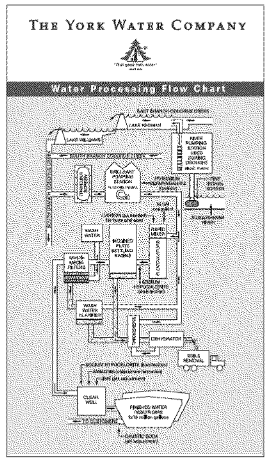
IPUMSU

1. Technical capacity

§ The physical and operational ability of a water system to meet SDWA requirements, including the adequacy of physical infrastructure and the technical knowledge and capability of personnel.

§ Elements

- Source-water adequacy and protection
- Infrastructure adequacy and improvement
- Technical knowledge and implementation



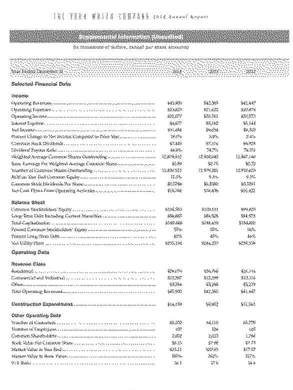
IPUMSU

2. Financial capacity

§ The ability of a water system to acquire and manage sufficient financial resources to allow the system to achieve and maintain compliance with SDWA requirements.

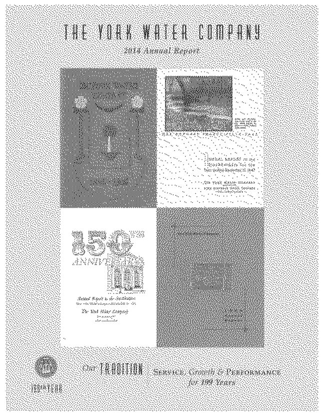
§ Elements

- Revenue sufficiency
- Credit worthiness
- Fiscal controls



3. Managerial capacity

- The ability of a water system to conduct its affairs in a manner enabling the system to achieve and maintain compliance with SDWA requirements, including institutional and administrative capabilities.
- Elements
  - Ownership accountability
  - Staffing and organization
  - Effective external linkages



Responding to capacity needs

- Remedial – “Redress”
- Tactical – “Reassess”
- Operational – “Reengineer”
- Organizational – “Reorganize”
- Structural – “Restructure”

IPUMSU

Role of water system planning

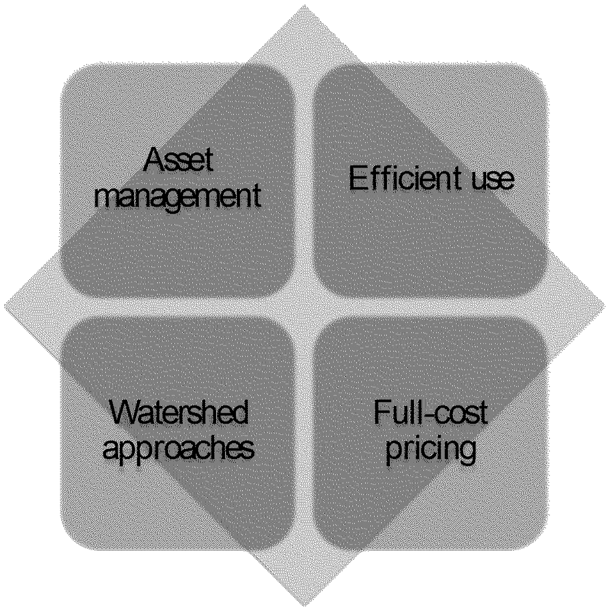
- Business plan
- Financial plan
- Management plan
- Water resource plan
- Contingency/emergency-response plan
- Capital facility plan
- Operation and maintenance plan
- Watershed plan
- Integrated resource plan
- Strategic plan

IPUMSU

Planning as process

- Planning is a dynamic and ongoing process (continuous improvement)
- Planning encourages strategic thinking by managers on a day-to-day basis, with internalization of goals and commitment to a strategy for achieving them
- Planning requires continual assessment and adjustments to changes in the external environment

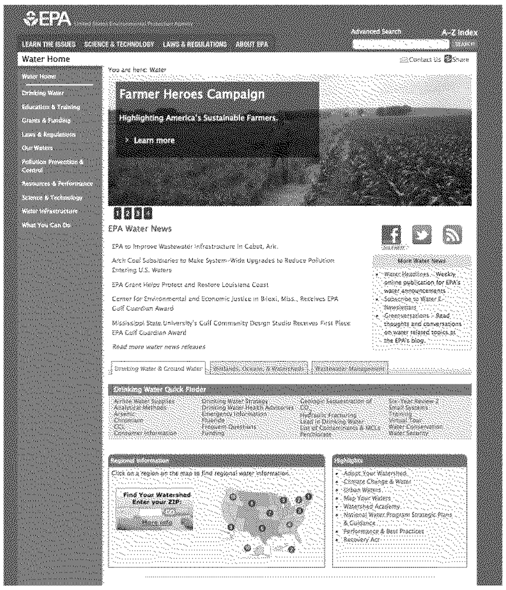
EPA's four pillars of sustainable infrastructure

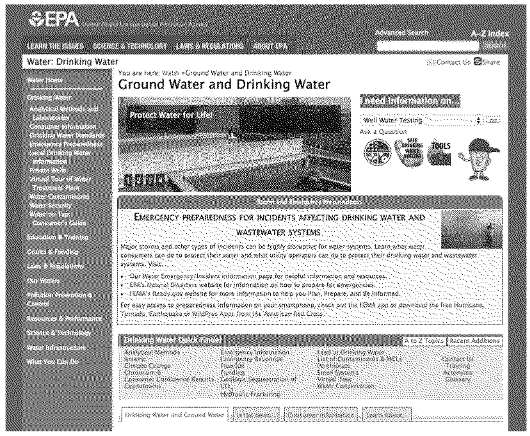


State public utility commission roles

- Coordinated regulation
  - Memoranda of understanding and informal communications
  - System identification and shared data
  - Drinking water SRF access
- Incentives for consolidation
  - Acquisition adjustments
  - Single-tariff pricing
  - Mandatory takeover authority
- Small-system methods
  - System of accounts
  - Simplified and flexible procedures
  - Cash needs and operating ratio ratemaking
- Expansion of commission jurisdiction
  - Water accounting, reporting, and full-cost pricing

EPA water websites





Resources on water

- Federal legislation
  - SDWA http://www.epw.senate.gov/sdwa.pdf
  - CWA http://www.epw.senate.gov/water.pdf
- US Environmental Protection Agency – Water
  - http://water.epa.gov/drink/
  - http://cfpub.epa.gov/surf/locate/index.cfm
- USEPA Small Systems and Capacity Development
  - http://www.epa.gov/safewater/smallsys.html
- AWWA Principles of Water Rates, Fees, and Charges (M1)
  - http://www.awwa.org/bookstore/product.cfm?id=30001
- International Water Resources Association (IWRA)
  - http://www.iwra.siu.edu/
- American Works Association
  - http://www.awwa.org/index.cfm?showLogin=N
- Water Research Foundation
  - http://www.waterrf.org
- United States Geological Survey
  - http://www.usgs.gov/water/

National Dialogue on Contaminants of Emerging Concern and Public Health [Project #4463]

ORDER NUMBER: 4463

DATE AVAILABLE: March 2014

PRINCIPAL INVESTIGATORS:
Rula A. Deeb, David L. Sedlak, and Elisabeth L. Hawley

OBJECTIVES

The term Contaminants of Emerging Concern (CECs) includes a variety of chemicals that have been detected in water supplies, are unregulated in the United States at the Federal level, and have real or perceived potential adverse effects. Examples include perfluorinated compounds, a variety of hormonally or pharmaceutically-active compounds, personal care products, and disinfection byproducts. Despite lacking definitive information on CECs, water utilities must make risk management decisions and choose how and what to communicate to th e public and media about CECs. Water utilities that collaborate with organizations with a broader knowledge of public health issues (e.g., local medical and public health organizations and spokespersons) can make more informed decisions and communicate more cohesive ly and completely.

To enhance communication and dialogue about the potential human health risks of CECs in drinking water among water utilities, public health agencies, researchers, and other organizations, the Water Research Foundation hosted an inter -disciplinary workshop that was attended by representatives from each of the se groups. Workshop objectives included the following:

- To broaden the national dialogue about the risks of CECs in drinking water by including public health professionals and other stakeholders in the discussion
- To bring the public health perspective into utility communications on CECs
- To promote dialogue and facilitate inter-disciplinary collaborations

The workshop was held in Washington DC over a two-day period (July 17 and 18, 2013). This report summarizes the workshop proceedings, discussion topics, and key recommendations to continue to broaden the dialogue on CECs and public health.

RESULTS

On the first day of the workshop, each of the 30 participants briefly introduced themselves and their organizations, described past and ongoing activities related to CECs and public health, and gave their individual perspectives on some of the key uncertainties and specific needs related to CECs. These issues provided a starting point for group discussion on the second day of the workshop. In the afternoon of the first day, invited speakers gave presentations on the human health effects of CECs in water supplies from the perspectives of a water utility, water quality researcher, public health practitioner, public health researcher, regulator, NGO, and risk communication specialist. Summaries of each presenter's perspectives are provided in Chapter 2.

On the second day, workshop participants dispersed into smaller groups and each group discussed the following three topics:

1. Define common understandings associated with CECs and public health
2. Identify technical uncertainties confounding the development of stronger statements about the public health risks of CECs in water
3. In light of the common understandings and technical uncertainties, identify improved CEC communication strategies

Key findings are summarized below, with more details provided in Chapter 3.

Common Understandings

Different disciplines and organizations approach the topic of CECs and public health from different perspectives. To lay the groundwork for identifying common goals among different organizations and fostering future collaborations, workshop participants formulated several statements to convey common understandings about CECs and public health that are shared by water quality groups, public health groups, and other types of organizations who were represented at the workshop.

A common goal of the groups represented at the workshop is to ensure that healthy and safe water is used by people nationwide. Workshop participants agreed that it was important to evaluate and take steps to reduce or prevent adverse environmental health effects of CECs. Because the CEC terminology is imprecise and may misleadingly group chemicals with dissimilar modes of action and health effects, workshop participants agreed that a better method or process was needed for grouping different classes of CECs to facilitate risk assessment, regulation, and communication.

Participants also agreed that there is a disconnect between the concerns of the public health community and those of the public. The public's perspective of CECs and other water quality contaminants is often shaped by media depiction (which is often negative and is sometimes alarmist), whereas public health researchers are more likely to research topics with known health effects. In the absence of definitive information about human health risks, it is important for water utilities to communicate what we do know about CECs with the public.

Workshop participants also agreed that the current system for regulating drinking water in the United States is not holistic. Regulations are reassuring to the public, and describing CECs as "unregulated" in drinking water can cause alarm. Workshop participants also expressed a common interest in developing an unbiased, peer-reviewed standard for assessing water quality and safety beyond compliance with existing regulations.

Technical Uncertainties

Workshop participants identified several technical uncertainties that confound the development of stronger statements about public health risks of CECs in water. Most of the uncertainties identified related directly to toxicology and the determination of human health effects. Currently, there is a lack of comprehensive studies of human health effects of CECs. Studies typically do not address advanced toxicological topics such as long-term effects, exposure to mixtures of different CECs, and population-level effects. There is also uncertainty in defining relevant human health endpoints when studying EDCs.

Other technical (and non-technical) uncertainties discussed by one or more groups related to CEC analytical methods; sources, transformations and occurrence; and the interpretation and communication of results to society. The groups identified the need for standardized, validated, and cost-effective analytical methods to inform occurrence studies and improve confidence in data quality. The current understanding of CEC sources, transformations in the environment, and exposure pathways is incomplete, resulting in technical uncertainties in assessing relative risk and risk management approaches. Another uncertainty identified by workshop participants related to the interpretation of human health risks and communication of these risks to the general public without unduly provoking alarm.

Improved Communication Strategies

The strategies for improving water utility communication s with the public and media on CECs can be categorized as either building partnerships with other organizations, adopting best practices for risk communication, or getting to know the audience(s) and tailoring the messages accordingly.

Enhanced Collaboration and Next Steps

Collaborations would be mutually beneficial for water utilities and public health groups. Water utilities are often placed in the spotlight and questioned about detections of unregulated CECs in water supplies. Utility representatives could benefit from partnerships with public health professionals who could attest to the safety and quality of water supplies. More broadly speaking, environmental engineers and researchers often have a limited understanding of toxicity and health effects of CECs. Tapping into the body of knowledge in the public health community would benefit risk management options and communications. The public health community would also benefit from a better understanding of water supply systems and water quality. One workshop participant expressed the desired outcome/goal of working collaboratively as follows: to bring public health perspectives to better inform the water community, leverage research findings. and ultimately lead to better decisions, priorities, enhanced communication, and improved research on water quality and on public health.

During the afternoon of the second day, workshop participants reassembled into one larger group and brainstormed several ways to facilitate local, regional, and national opportunities for future collaboration, including cross-disciplinary input from individuals/experts, hosting cross-disciplinary technical meetings and workshops, interagency collaborations, shared online resources and networking, local collaborations and networking, and the use of focus groups and pilot studies on inter-disciplinary collaborations.

Next steps to maintain inter-disciplinary dialogue on the health effects of CECs in water were also identified by the workshop participants. Broadly speaking, the discu ssion was focused around several themes, including developing centralized communication tools, conducting cross-discipline outreach and public outreach, convening future workshop and conferences, assessing the current state of knowledge and defining key messages, and funding research to advance the state of knowledge and inform future regulatory guidance.

CONCLUSIONS AND RECOMMENDATIONS

This workshop led to cross-disciplinary interaction and information exchange between utilities, water quality researchers, public health researchers and practitioners, regulators, and other groups. Workshop participants recognized the value of future collaborations between water quality and public health groups. Participants identified common ground between different organizations and discussed next steps to maintain dialogue moving forward. The workshop expanded attendees' professional networks and catalyzed plans for collaborative outreach efforts.

In addition to publishing this report for the benefit of those who were unable to attend the workshop, the Water Research Foundation plans to implement several specific suggestions to broaden the national dialogue on CECs and public health.

The project team also prepared a series of Overview papers that summarize topics presented at the workshop (i.e., CEC regulations, risk communication, water utility activities, medical practitioner activities, water quality research, and public health research). The Overviews are included as Appendix C in this report, are available to download individually on the 4463 project page on the WRF Website (links below), and will be shared with water utilities through the online EDC Network for Water Utilities (http://edcnetwork.net). The Overviews echoed the six perspectives provided by the invited speakers during the first day of the workshop: water quality practitioner, water quality researcher, public health practitioner, public health researcher, regulator, and communication specialist.

- Risk Communication about CECs
- Regulation of CECs in Drinking Water
- Public Health Research on CECs
- Medical Practitioners and CECs
- Water Utility Activities Related to CECs
- Water Quality Research on CECs

The Water Research Foundation is conducting a webinar in April 2014 to promote cross-discipline interaction about CECs and public health. This webinar will be publicly available and archived for viewing at a later date. Workshop proceedings and key findings will be shared with the American Water Works Association (AWWA) Committee on Water and Health Technical Advisory Workgroup. The project team has already submitted abstracts for a special topic session at several national conferences attended by water quality professionals and/or medical groups. Workshop participant recommendations will be considered by the Water Research Foundation Technical Advisory Committee on CECs and Risk Communication in setting research agendas in future years.

APPLICATIONS

Workshop proceedings can be used by water utilities and by the drinking water community to better improve their understanding of the collective perspective of public health groups, regulators, and other organizations on the health effects of CECs. By implementing the recommendations in this report, water utilities can take steps to broaden the dialogue on CECs, improve their understanding of health effects, collaboratively address technical uncertainties on CECs, and improve communication strategies with other researchers, regulators, and the public.

The Lead Industry and Lead Water Pipes "A MODEST CAMPAIGN"

| Richard Rabin, MSPH

Lead pipes for carrying drinking water were well recognized as a cause of lead poisoning by the late 1800s in the United States. By the 1920s, many cities and towns were prohibiting or restricting their use. To combat this trend, the lead industry carried out a prolonged and effective campaign to promote the use of lead pipes. Led by the Lead Industries Association (LIA), representatives were sent to speak with plumbers' organizations, local water authorities, architects, and federal officials. The LIA also published numerous articles and books that extolled the advantages of lead over other materials and gave practical advice on the installation and repair of lead pipes. The LIA's activities over several decades therefore contributed to the present-day public health and economic cost of lead water pipes.
(Am J Public Health. 2008;98:1584–1592. doi:10.2105/AJPH.2007.113555)

SINCE THE CENTERS FOR Disease Control and Prevention began to establish acceptable blood lead levels for young children in the 1960s, the concentration at which blood lead levels have been thought to have significant health effects has steadily declined. That concentration has been reduced from 60 µg/dL to the current level of 10µg/dL, which was established in 1991.[1] Research conducted in the past few years, however, suggests that there are health effects below that level, and that IQ declines at a faster rate below 10µg/dL than above.[2,3]

Although lead-based paint is the single most important contributor to elevated blood lead levels in children, if just a few micrograms of lead per deciliter of blood are of concern and if we are to truly prevent the health effects of lead exposure in the United States, then water, as well as other sources of lead, must also be addressed. Water consumption is estimated to contribute, on average, about 10% to 20% of a child's total lead intake, and for infants fed formula, 40% to 60% of their lead exposure.[4]

In the past 2 decades, legislation and regulations at the federal level have helped to reduce water lead concentrations.[5–7] Nevertheless, lead in drinking water continues to be a public health concern. Over the past several years, significantly elevated lead levels in many cities have provoked public outcry. Lead-contaminated water in homes and schools has been detected in Boston, MA[8,9]; Durham, NC[10]; and Camden, NJ,[11] among many others. In Washington, DC, in 2004, there was considerable public concern when more than half the homes with lead service pipes were found to exceed the Environmental Protection Agency's (EPA's) action level of 15 parts per billion.[12] Public interest in this matter is evident from a computer search of general interest and business publications for the period between January 1995 and April 2007 with the terms *water* and *lead pipes* that yielded 220 articles.[13]

Recent US history has been marked by many environmental and public health crises initiated or exacerbated by corporate actors despite knowledge (or reasonable suspicion) that an activity or chemical exposure was particularly hazardous. Childhood lead paint poisoning,[14,15] asbestos-related deaths,[16,17] and tobacco-related diseases and mortality[18] are a few of these. Here I review the evidence that lead pipes for water distribution were installed well after they were considered a public health threat and examine the corporate activities and other factors contributing to their continued use.

BACKGROUND

Although the use of lead pipes for water distribution has a centuries-old history, installation of lead pipes in the United States on a major scale began in the late 1800s, particularly in the larger cities.[19] By 1900, more than 70% of cities with populations greater than 30000 used lead water lines.[19] Although lead was more expensive than iron (the material of choice until that time), lead pipes had 2 significant advantages over iron ones: they lasted much longer than iron (about 35 years compared with 16) and, because they are more malleable, they could be more easily bent around existing structures.[19]

Concerns about the potential toxicity of lead from water that passes through lead pipes were documented even before lead came into widespread use. In 1859 a collection of articles was published presenting the views of various engineers, physicians, and public health officials. The editor of those articles began by noting the objections raised by residents of New York City and Boston to the introduction of lead for service pipes (the pipes that carry water from the street main to a building) and indoor plumbing:

> In other cities of the United States and of Europe the same feeling has at times more or less agitated the public mind, without leading however, thus far, to any serious modification of the long established practice [of installing lead pipes], that I am aware of, except in Hartford, Conn.[20(pi)]

With the large-scale introduction of lead service pipes, numerous public health and newspaper accounts of lead poisoning from drinking water began to appear with increasing frequency. From the late 1800s to the early 1900s, numerous journal articles and reports appeared documenting the dangers to health of lead pipes.[21–28] One published bibliography in 1943 listed more than 100 articles and reports in English on lead poisoning from drinking water.[29] In 1890 the Massachusetts State Board of Health advised the state's cities and towns to avoid the use of lead pipes.[19] By the turn of the century, there was little doubt in the public health community that lead water pipes were to be avoided. By the 1920s, many cities had concluded that the engineering advantages of lead were outweighed by the public health risks, and local and state plumbing codes were revised to prohibit or limit the use of lead in pipes for water distribution.[19,30]

THE LEAD INDUSTRIES ASSOCIATION

The Lead Industries Association (LIA) was formed in 1928 as the lead industry's trade organization. Its membership encompassed both producers and users of lead products and included all the major producers. Lead mining and manufacturing was dominated by just 6 companies (all LIA members) until the 1960s: the National Lead Company, American Smelting and Refining, Anaconda, the Hecla Mining Company, Eagle Picher, and the St Joseph Lead Company.[31] The National Lead Company was by far the largest.[32]

As would be expected of an industrial trade association, a central function of the LIA was to promote the sale of its members' products. Lead pipe, of course, was one of them.

> We are endeavoring to keep abreast of any impending changes in plumbing codes. . . . We have also been investigating the use of lead in service pipe and other applications. We have been accumulating useful information pertaining to lead and expect soon to make it the basis of a modest educational campaign within the limits of the current budget.[33]

Although most of the lead industry's efforts to promote the use of lead in plumbing emphasized the positive (i.e., the advantages of lead over other materials), there clearly was some concern that the potential health hazard of lead pipes could jeopardize the market for lead pipes. In his 1929 report to the membership, the secretary noted that,

> *"Water is much more wholesome from earthenware pipes than from lead pipes. For it seems to be made injurious by lead, because white lead paint is produced from it; and this is said to be harmful to the human body."*
>
> *Vitruvius, first-century-BC Roman architect and engineer, De architectura*

> Of late the lead industries have been receiving much undesirable publicity regarding lead poisoning. I feel the association would be wise to devote time and money on an impartial investigation which would show once and for all whether or not lead is detrimental to health under certain conditions of use.[33]

This public alarm over lead exposure can be attributed at least in part to reports in the popular press. In 1924, the *New York Times* reported on a medical conference that highlighted nonindustrial sources of lead, including lead paint.[34] During the Depression, it was not uncommon for poor persons to use old battery casings for fuel, and there were newspaper reports of families being lead poisoned.[35,36]

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Although subsequent LIA reports implied that the secretary primarily had lead paint in mind as the cause of this adverse publicity, the association also felt the need to address the public's concerns regarding lead pipes. For instance, in 1930 the LIA investigated a case of lead poisoning in conjunction with the Charleston Water Works.[37] (The findings of the investigation were inconclusive: lead service pipes had recently been installed, but contamination of the home was possible because the father was a house painter.[38])

From its inception until at least the early 1970s, the lead pipe manufacturers and their association used a wide variety of methods to promote their products, including the publication of numerous educational materials and model standards, attendance at professional meetings, and lobbying of local, state, and federal government agencies. In 1931, the LIA prepared a booklet and a "model" standard for lead pipes.[39] It also published the first edition of the book, *Useful Information About Lead*,[40] which described the many products made of lead. The chapter on plumbing advises that "the best material in a water service, though it may be slightly more expensive at first, is really an economy, and the best material is usually lead."[40(p74)] The exception, it notes, is

> when the water is very soft, or of swampy or peaty origin, that lead should not be used, but under those conditions other metals are also soluble, so lead may be used by adding a little sodium silicate solution to the water, as is done occasionally–or using tin-lined lead pipe.[40(p74)]

The LIA's 1934 annual meeting minutes record an "intensive" effort to reverse the downward trend in the use of lead pipes; contacts are reported with city officials, master plumbers, and plumbing associations. Over the next 2 decades, the LIA continued to promote lead pipes through contacts with plumber organizations and local boards, by lobbying federal agencies, and by publishing newsletters.

The association issued a bulletin for distribution to water works officials. LIA members who produced plumbing supplies made donations to the Plumbing and Heating Industries Bureau. The usefulness of cooperation with that organization was clear:

> As the Bureau was founded to promote the wider use of modern plumbing, it is essential that the role which lead plays in modern plumbing installations be not overlooked. Our cooperation with this Bureau will insure that lead receives ample and proper consideration.[41]

A key part of the campaign to boost sales of lead pipe was the hiring of an agent to, in the words of the LIA secretary,

> work on our behalf and I am pleased to report that the work has more than met with an excellent reception. It has grown so quickly and so strongly that it has reached a stage at which it is really too large a problem for one man working in the Eastern part of the United States alone to handle. We have rekindled an interest on the part of master and journeymen plumbers in the use of lead. We have pointed out to municipalities the risks that they run in advocating substitutes for lead and have received the endorsement of numerous important State master plumbers and journeymen plumbers associations with whom the subject has been discussed. . . .Since the first of the year, even greater advances have been made and we firmly believe that in a comparatively short time there will be growing evidence of the advantageous results accuring [sic] to our members from this work.[41]

The report of the LIA's agent, Robert Dick, enumerates the year's specific accomplishments:

> (a) One code approved and put into operation, requiring lead wherever it is advisable to use lead in the plumbing system.
>
> (b) One town enforcing the use of lead throughout plumbing systems although not called for by its code.
>
> (c) Nine cities and towns with revised codes calling for lead throughout. These codes now ready to be submitted to the various councils for adoption.
>
> (d) Forty-eight cities and towns working on revisions to require lead throughout, but with the codes not yet ready for submission to council.
>
> (e) Forty-eight cities and towns in which no immediate action can be taken due either to political or financial conditions, or in a few cases, to opposition to the use of lead.[41]

Although this report does not mention the health-related reasons lead had been losing ground to other plumbing materials, it does discuss the economic pressures brought on by the Depression:

> The present time is a critical time for this work because during the depression years, the plumbing industry has experienced intense competition from the installations of handymen and others not actually engaged in the plumbing business so that the plumbers are now looking for anything that will protect their interests against these outsiders.[41]

Dick went on to explain that requiring the use of lead would be in the interest of professional plumbers because the installation of lead fixtures and pipes required a level of skill that others did not possess. This self-interest on the part of plumbers probably accounts for the reported success that the LIA had in persuading the numerous plumber organizations to endorse the use of lead. Even into the 1940s, this economic motivation played some role in plumbers' desire to allow or even require lead. In Denver in 1947, when a proposal was made to permit iron and steel for domestic plumbing, the master plumbers organization blamed "self-seeking speculative builders," and one journeyman plumber was quoted as attributing the proposal to an attempt to "move '90-day wonders' and handymen into an industry which protects the health of the community."[42(p77)]

According to the secretary, 1938 was a banner year for the LIA. The association now had 3 representatives working on its Plumbing Promotion Program. Most of their time was taken up that year by attendance at 24 state conventions of master plumbers and by speaking at 19 of them. Outreach materials were produced and distributed to plumbers who were actively attempting to change their local building codes. The association's trade publication, *Plumbers' Forum*, had a mailing list of 22500. Plans were announced to "work with various housing authorities to have lead specified in the plumbing of . . . large developments."[43] Plumbing code regulations were changed in Pennsylvania (to require lead for plumbing), Massachusetts (removal of the 5-foot limitation on lead), and in dozens of other cities. In this connection, the secretary reminded the members that

> It must be remembered that adoption of laws, as above, is slow work, but once adopted, make a relatively permanent requirement of lead. In many cities, we have successfully opposed ordinance or regulation revisions which would have reduced or eliminated the use of lead. We have prevented elimination of lead work from examinations for plumbers' licenses in New York and other cities, and have introduced license examinations with a lead work requirement in many places where no examinations for lead work were formerly required.[43(pp3–4)]

In cities where lead had fallen out of favor for a number of years, there was the danger that, even if a revised plumbing code reinstated lead as a permitted or required material, there would not be a sufficient number of plumbers trained in its installation and repair. Consequently, the LIA expended some effort to train a labor force skilled in working with lead. Cooperating with the Federal Committee on Apprentice Training, in 1938 the LIA established classes in several cities, including Chicago; Pittsburgh; San Francisco; St Paul, Minnesota; Wilkes-Barre, Pennsylvania; Youngstown, Ohio; and Phoenix. In addition, it began preparation of the section on lead of the *Standard Text on Plumbing*, to be published by the National Association of Master Plumbers.[44]

The pipe manufacturing members of the LIA were also concerned about the failure of lead plumbing, stemming from poor quality goods, and thereby leading to the discontinuation of lead products. In response, the LIA developed a series of standards for various lead plumbing products, including pipes and caulking. According to the LIA secretary, numerous entities adopted these standards, including the American Water Works Association, New York City, and several other cities.[44]

In 1940 several federal agencies including the War and Navy Departments, the Public Buildings Administration, and the US Housing Authority were involved in major construction projects for "defense building." As a result, LIA staff expended much effort in Washington to ensure the inclusion of lead in the specifications for plumbing. Their efforts apparently met with considerable success, because "lead plumbing is now included in many Federal government master specifications where it had been excluded for many years."[45] But because these specifications were only optional, association staff had to make personal visits to many of the federal construction projects to persuade those in charge that lead was preferable to other materials. These efforts were also successful, according to the secretary.

At the same time, the LIA initiated or continued several activities that it expected would have long-term benefits for the lead industry by institutionalizing the use of lead in plumbing nationwide:

> A simplified standard for lead fittings was put into effect at the end of the year. Also the first steps toward obtaining a Commercial Standard for lead pipe, traps and bends and calking lead, promulgated by the National Bureau of Standards, were taken. It is expected that Federal Specifications for lead pipe, traps and bends will follow soon after adoption of the Commercial Standards.[45(p6)]

An initial success was the publication in 1940 by the Bureau of Standards of a new *Plumbing Manual*,[46] which served as the basis for the specification of lead plumbing in federal construction projects. The manual has a cautionary note: "Lead piping in water-supply lines shall not be used unless it has been definitely determined that no poisonous lead salts are produced by contact of lead with the particular water supply."[46(p14)] However, given the numerous factors that could affect a water supply's plumbosolvency, it is not clear how it could be known for certain in advance that

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"no poisonous salts" would be dissolved in the water.

By the 1940s, the lead industry had become alarmed at the public's growing wariness of all things lead, including lead pipes:

> There is hardly an outlet for lead to which one can turn today without encountering, in some measure, the question of the lead hazard to the public. So fundamental is this problem to the future welfare of the lead industries and the continued manufacture and use of many important lead products, such as white lead, red lead, litharge, sheet lead and lead pipe that unless some immediate attention is paid to the problem above and beyond what the Association has already accomplished and is currently doing, the opposing forces may grow strong enough to do us injury which it would take years of work to correct.[47]

"I cannot overemphasize [the] importance [of our health and safety work]. The toxicity of lead poses a problem that other nonferrous industries generally do not have to face. Lead poisoning, or the threat of it, hurts our business in several different ways."

Between 1941 and 1949, the LIA reduced its plumbing campaign field staff from three to two. However, it continued its usual promotional work around lead pipes:

> The promotional work in the plumbing and water works field continues as in the past . . . with master and journeyman plumbers, plumbing inspectors, instructors and others, to see that lead is adequately provided for by plumbing codes through the country and to see that plumbers are trained to know how to handle and install lead work.[48(p5)]

In the LIA's 1952 book *Lead in Modern Industry: Manufacture, Applications and Properties of Lead, Lead Alloys, and Lead Compounds*,[49] the industry continued its promotion of lead service lines; more than 1500 copies were sold in the first 2.5 months after publication.[50] However, this edition did not caution the reader (as it did in 1931) about conditions under which lead might not be advisable.

Throughout the 1950s, the LIA continued its outreach to plumbing and related professionals. *Lead*, the LIA's trade journal with a quarterly publication schedule and a distribution list of more than 50000, carried a steady stream of articles on plumbing.[51] The textbook, *Lead Work for Modern Plumbing*,[52] which was first published in 1952, had by early 1956 reached a total distribution of more than 6500.[53]

The theme of a continuous, serious threat to the lead industry because of the public's alarm over the danger of lead exposure is again made explicit a few years later by the LIA's secretary:

> I cannot overemphasize [the] importance [of our health and safety work]. The toxicity of lead poses a problem that other nonferrous industries generally do not have to face. Lead poisoning, or the threat of it, hurts our business in several different ways. While it is difficult to count exactly in dollars and cents, it is taking money out of your pockets every day.[54(p4)]

As before, he is most concerned about lead paint, but he makes clear that lead pipe sales are also at risk:

> There is a law suit now pending in Milwaukee in which an apartment building tenant is suing the owner for $200,000 damages for alleged lead poisoning from water passing through the building's lead service pipe. Success of a suit like this could well mean the end of lead services not only in Milwaukee, but in Chicago and many another city, amounting to thousands of tons of lead a year. We are working with the defense, and although the case does not come to trial for some months, our latest information is most encouraging.[54(p4)]

Promotional activities continued at least until 1972, when the LIA issued the sixth printing of its text *Lead Work for Modern Plumbing*.[52]

THE HISTORICAL CONTEXT

Given the medical and public health view that lead pipes were a clear danger to the public, one may ask how the lead industry could persist, with at least moderate success, in promoting and selling lead water pipes. Several factors contributed. One relates to the lingering doubts among water engineers and water authorities about the risks of lead pipes. Throughout the 19th century, attempts had been made by some physicians to link lead water pipes to cases of severe illness. However, these were met with considerable skepticism by water authorities, most of the medical community, and the general public: not everyone consuming water from lead pipes became sick, many of the symptoms of lead poisoning mimic those of other diseases, and the medical tests for diagnosing lead poisoning were not well developed. However, by the early 20th century, publication of the many medical articles and reports of the previous 20 to 30 years had made a compelling case for a relation between lead water pipes and lead poisoning.[19]

As indicated above, plumbers and water works engineers and officials favored lead pipes for their durability and other practical advantages. In addition, an extensive discussion among water works professionals and officials at their meetings and in their publications

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clearly indicates that many of them were not as convinced as their counterparts in the public health community that lead water pipes were an unacceptable health hazard.[55–63] This divided opinion can be seen in articles in professional journals, plumbing texts, and publications of more general interest. For example, the author of an article in the *Journal of the American Water Works Association* in 1938 believed the dangers of lead pipes to be exaggerated:

> Lead ions seem to have a bad reputation, although some of it is not deserved when it comes to the traces found in most purified water supplies. If the very small amounts which persons ingest by drinking water and eating food, were as harmful as some people believe them to be, there would be many more cases of lead poisoning than are known to occur.[57(p248)]

In 1934 and again in 1945, the *American City*, a magazine reporting on general and technical developments in the urban environment, approvingly reported on the installation and longevity of lead service pipes.[64,65]

On the other hand, Harold Babbitt, a professor of sanitary engineering, strongly opposed the use of lead water pipes:

> Lead is sufficiently soluble in water to offer a real menace to health and for this reason its use in contact with potable water should be restricted if not prohibited. Tests by the Massachusetts State Board of Health have shown lead content as high as 3 to 5 parts per million in natural waters and an increase of 50 to 100 per cent, and even more after the water has been standing in lead pipe. Since 0.5 parts per million is considered dangerous to health, the use of lead in water pipe or in contact with potable water should be prohibited.[63(p267)]

A common, middle point of view was that lead pipes should not be installed where the water supply was "soft" (lacking in certain minerals, primarily magnesium and calcium) or high in carbonic acidic (carbon dioxide dissolved in water).[55,56,59,61] The LIA's Robert Ziegfeld also advanced this argument but suggested that conditions that affected lead would also attack other metals. (He neglected to mention, however, that other metals, such as iron and copper, are not as toxic as lead.[62]) Another argument in favor of the use of lead pipes was that over time a thin coating forms on the interior pipe surface that prevents further corrosion. Furthermore, various chemicals could be added to the water to reduce the acidity. However, research and experience from the mid-1800s to the early 1900s in the United States and Great Britain provided considerable evidence that many other factors as well (not often discussed by water works professionals) could influence the plumbosolvency of a water supply.[19] In other words, whereas a water supply that is hard or alkaline is less likely to result in an unhealthy concentration of lead, such a result may occur because of other factors. An example was provided by a 1928 study of several towns and cities in Illinois that had very hard water. In that study, lead levels ranged from 0.02 to 0.50 parts per million (1.3 to 33 times the modern EPA standard).[66]

The lead industry also benefited from the absence, at the federal level, of the regulation of environmental health hazards. As several authors have noted, before the 1960s, the federal government did not play an active role in protecting the public from environmental or occupational hazards.[67–70] In the Progressive Era of the first 2 decades of the 20th century, the federal government's legitimate role was to investigate hazards and recommend solutions to the responsible industry but not to legislate changes. In her investigations of the occupational hazards in several industries, including those with lead exposure, Alice Hamilton (a pioneer in occupational medicine in the United States) highlighted serious health hazards and made recommendations for their abatement but did not suggest legislative interference.[67] The next 4 decades marked a period of even less government activism, as manufacturers were assumed to investigate and control the hazards that they created.[67] The public health disasters of asbestos and lead paint, noted above, can be seen as products of this laissez faire era.

Another factor impeding a greater focus on lead pipes was the much greater concern regarding infectious diseases compared with the attention paid to environmental toxins in the first half of the 20th century.[71] Prevention of water-borne diseases was a particular focus of attention for professionals who designed and installed domestic plumbing. Some indication of this greater concern about communicable disease can be seen from a computer search of *American Journal of Public Health* articles. The search terms *water* and *cross-connection* (a common cause of infectious disease from drinking water) yielded 20 articles for the 1930 to 1950 period, whereas *lead pipes* yielded only 3. Indeed, at least 1 of the National Lead Company's advertisements promoted lead pipes as providing a more "sanitary" water supply.[72]

CONTINUED USE OF LEAD PIPES

The year 1930 is often given as the date after which few lead water pipes were installed in the

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United States,[19,30] and this downward trend was almost certainly the case. However, the reports and meeting minutes of the LIA cited above indicate that it had some success in slowing, and even in some cases reversing, that movement. Evidence of continued installation of lead pipes comes from other sources as well. The plumbing codes of some major cites, including Boston[73,74] (JE Richardson, Boston Water and Sewer Commission, personal communication, January 29, 2007); Milwaukee, WI[54]; Philadelphia, PA[74]; Denver, CO[42]; and Chicago, IL,[43,75] still called for lead many years, even decades, beyond 1930. Besides these major cities, there is much suggestive evidence, both direct and indirect, that the installation of lead water pipes continued on a significant scale throughout the United States well beyond 1930. Cities and states usually based their plumbing codes on 1 of 3 model codes: the Building Officials and Code Administrators' (BOCA) plumbing code, the International Council of Building Officials' Uniform Plumbing Code, and the Southern Building Code Congress' Standard Plumbing Code. All 3 listed lead as an acceptable material for water distribution for several decades beyond 1930 (until 1981, 1988, and 1977, respectively).[76–82]

Of course, the listing of lead as a permitted material in plumbing codes does not, by itself, mean that it actually continued to be used on a large scale. However, the LIA itself confirmed such use of lead pipes for water distribution. At a 1963 symposium on lead, the LIA's Robert Ziegfeld stated that one of the principal uses of lead in construction was pipes for water distribution. "Pipe and extruded products" consumed 20 000 tons in 1962.[83]

In 1984 the EPA conducted a survey of 153 public water systems across the country to determine the extent of the use of lead pipes.[75] Most (91) of the systems in the survey had populations of over 100 000. Of the municipalities surveyed, 112 (73%) indicated that they had in the past installed lead service lines, and 5 specifically stated that lead had been permitted well beyond 1930. Seven systems answered that they currently (as of 1984) used whatever their code permitted. Chicago acknowledged that it still sanctioned the installation of lead service pipes. With passage of the Safe Drinking Water Act Amendments of 1986,[5] installation of lead water pipes was finally prohibited nationwide.

The number of lead service lines installed in US cities since the 1920s probably cannot be estimated with any degree of certainty. In the EPA's 1984 survey, approximately 30% of the respondents could not offer any estimate of the number of lead service lines remaining in their cities. Nevertheless, it can be stated that with so many large cities that continued to permit the use of lead pipes, such as Boston; Chicago; San Diego, CA; Philadelphia; and Milwaukee among others, the number is likely quite significant.

DISCUSSION

Although most cities in the United States were moving away from lead water pipes by the 1920s, it appears that this trend was not universal. National model plumbing codes approved lead into the 1970s and 1980s, and most water systems based their regulations on those codes. Federal guidelines and specifications also sanctioned lead pipes at least into the 1950s. Water system engineers were debating the pros and cons of lead at least into the 1940s. Perhaps most telling was the active campaign carried on by the lead and pipe manufacturers' trade organization, the LIA. To maintain sales of lead pipe, the LIA lobbied the government at all levels and targeted the people who both designed and installed water distribution systems with outreach and educational material and other resources. The association carried on its promotional campaign into the 1970s.

As noted in the introduction, recent research strongly suggests that lead exposure has health effects of public health significance below the level of concern designated by the Centers for Disease Control and Prevention. Indeed, no threshold for the effects of lead on cognition has yet been identified.[84] The number of children potentially affected is quite high. More than one quarter (25.6%) of children aged 1 to 5 years in the United States had a blood lead level at 5 μg/dL or higher in 1994 according to the third National Health and Nutrition Examination Survey.[85] Several recent studies also point to serious health effects in adults at very low blood lead levels, including cancer,[86] cardiovascular disease,[86,87] peripheral arterial disease,[88] and death from all causes.[86] Therefore, although lead-based paint is the most significant source of childhood lead exposure, and occupational exposure is the main source for adults, we will have to address the contribution of water if we are to make acceptable progress in further reducing blood lead levels.

Although the number of lead service lines and other water distribution pipes installed as a result of the influence of the LIA and its pipe manufacturing members cannot be quantified, it is surely substantial. The American Water Works Association conducted a national survey to estimate the cost of replacing lead service lines.[89] The average cost per replacement was $3200, with a range of $750 to $16 000. The Washington, DC, water authority appropriated $300 million to replace 23 000 lead service lines, plus some portion of 27 000 lines of unknown material.

Despite a voluminous literature on the dangers of lead water pipes, and based on such knowledge, a national trend to restrict and prohibit the use of lead for water distribution, the lead industry continued its promotion and sale of lead pipes for several decades. Note also that the LIA and its corporate members carried out a similar campaign to promote lead paint long after its hazards became known[14,15] and are currently defending themselves against lawsuits by dozens of cities and states.[90,91] In fact, at least two LIA members, the National Lead Company and Eagle Picher, manufactured both lead paint and lead pipes. Although the use of these products has long since ended, our cities and towns, and society as a whole, are still paying the price. ■

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What's Next after 40 Years of Drinking Water Regulations?†

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The quality of drinking water in the United States has continued to improve over the past 40 years. The formation of the U.S. Environmental Protection Agency (USEPA) in 1971, the passage of the initial Safe Drinking Water Act (SDWA, PL 93-523) in 1974, and the passage of the 1996 SDWA Amendments (PL104-208) represent significant progress in drinking water quality. While the widespread adoption of filtration and disinfection in the early 1900s virtually eliminated waterborne typhoid fever, some residual risks still remained 40 years ago. These national regulatory developments compelled USEPA and the drinking water community to address these remaining risks in drinking water and optimize risk reduction for the public.

Introduction

The quality of drinking water in the United States has continued to improve over the past 40 years. The formation of the U.S. Environmental Protection Agency (USEPA) in 1971, the passage of the first Safe Drinking Water Act (SDWA, PL 93-523) in 1974, and the passage of the 1996 SDWA Amendments (PL 104-208) represent significant progress in drinking water quality. While the widespread adoption of filtration and disinfection in the early 1900s virtually eliminated waterborne typhoid fever, some residual risks still remained 40 years ago. These national regulatory developments compelled USEPA and the drinking water community to address these remaining risks in drinking water and optimize risk reduction for the public.

The History of the Laws and the Regulations. Although the history of the SDWA and the resultant regulations is available in detail elsewhere (*1*), a short review of drinking water policy evolution is useful here. Prior to the passage of the first SDWA in 1974, the U.S. Public Health Service (USPHS) established guidelines that the states generally used in developing their own state-level regulations. These early guidelines were important in promoting filtration and reliable chlorine disinfection as part of the multibarrier concept for drinking water treatment in the early 1900s. This approach was responsible for the virtual elimination of waterborne typhoid fever in the United States by the 1940s, conquering a disease that accounted for 0.35 deaths per 1000 people in the United States at the turn of the century (*2*). It is notable that this dramatic public health breakthrough was achieved without any regulations specifying disinfectant concentrations and contact times or chlorine residuals. In fact, the most significant drinking water risks were eliminated without any regulations. Admittedly, the illnesses and deaths from typhoid and cholera were easy to observe and the solutions were relatively simple, but both the risks and the solutions are policy issues that will be discussed later in this paper.

The 1974 SDWA shifted the federal role from developing guidelines developed by the USPHS that the states could adopt (or not) to USEPA developing enforceable standards. USEPA's standard-setting process under the SDWA is basically a two-step process. First, a maximum contaminant level goal (MCLG) is established. The MCLG is strictly a health-based goal and is not enforceable. USEPA typically sets the MCLG at zero for carcinogens. The maximum contaminant level (MCL) is the enforceable standard and is established setting the MCL as close to the MCLG "as feasible". Setting the MCL takes into account several factors such as analytical method feasibility and treatment feasibility as defined by the SDWA. Since USEPA has a policy of setting the MCLG at zero for carcinogens, those MCLs are typically based on analytical feasibility. The benefit-cost analysis (BCA) and the national impacts are additional critical components in setting the MCL. A treatment technique (TT) can be established when setting a MCL is not feasible.

The 1974 SDWA shifted the federal-state relationship in another aspect, in that the states were now *required* to adopt their own regulations "no less stringent than" the federal regulations to maintain "primacy" for state-level drinking water oversight programs. All of the states except Wyoming maintain primacy for their drinking water programs, and USEPA is responsible for direct implementation of the drinking water program in Wyoming, the District of Columbia, the territories, and most of the Indian tribes. USEPA provides a portion of the funding necessary for the states to run their programs and funding is an issue that will be discussed later in this paper.

Using the USPHS guidelines as a foundation, EPA finalized the National Interim Primary Drinking Water Regulations (NIPDWRs) that addressed 22 well-known chemical and microbial contaminants as the first set of standards under the 1974 SDWA (*3*). Including the NIPDWRs, EPA finalized nine drinking water regulations between 1975 and 1996: NIPDWRs (*3*), total trihalomethanes (TTHM) Rule (*4*), fluoride (*5*), phase I volatile organic chemicals (VOCs) (*6*), surface water treatment rule (SWTR) (*7*), total coliform rule (TCR) (*8*), phase II rule (*9*), lead and copper rule (LCR) (*10*), and phase V rule (*11*).

The 22 years of the drinking water regulatory program between the 1974 SDWA and the 1996 SDWA Amendments could best be described as a tug-of-war between Congress, USEPA, and the courts. USEPA had to wrestle with extremely complex policy issues such as identifying the critical contaminants, determining what levels were "safe" (an extremely debatable issue even today), determining what analytical methods and treatment technologies were feasible, and setting standards based on cost-benefit analyses and other factors. All of the issues were constrained by limited research and limited federal resources.

Frustrated by USEPA's lack of regulatory progress, Congress amended the SDWA in 1986 (PL 99-339). These amendments established a strict regulatory schedule for USEPA, requiring the agency to regulate 83 contaminants in the first five years and then 25 new contaminants every three years thereafter. If USEPA had continued along on this regulatory treadmill, more than 260 contaminants would be regulated today, and likely, many of these contaminants may never have been detected in drinking water or else detected at very, very low concentrations.

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To meet this schedule, USEPA developed standards from 1986 - 1992 for several contaminants, primarily in the phase II and phase V rules that significantly increased the number of regulated contaminants. The phase II rule set new standards for 27 organics and inorganics, revised 11 existing standards, deleted one existing standard (silver). The phase V rule set new standards for 22 organics and inorganics, and revised one existing standard (endrin). The number of regulated contaminants increased significantly from 22 in 1975 with the initial NIPDWRs to 84 in 1992 (a 282% increase) with the phase V rule. The contaminants regulated from 1975 - 1992 came from the list of 83 contaminants in the 1986 SDWA Amendments previously mentioned.

Despite this effort, USEPA soon missed several statutory deadlines and was sued by the Bull Run Coalition, an environmental advocacy group (1 F.3d 1246, Bull Run Coalition, et al., v William K. Reilly, 1993). The litigation led to a series of negotiated deadlines for future regulations. The deadlines were missed again. This cycle of litigation, setting and missing deadlines, and more litigation continued through the early 1990s and frustrated all of the parties involved. The water utilities were frustrated because deadlines kept shifting and planning for treatment improvements for compliance was problematic. USEPA was frustrated because resources were wasted on litigation actions. Congress was upset with USEPA for missing statutory deadlines. The increasing pressure to fix the drinking water regulatory program throughout this time frame led to the 1996 SDWA Amendments (PL 104-208).

The Turning Point in Drinking Water Policy. The 1996 SDWA Amendments represented a shift in drinking water policy from a regimented regulatory schedule to addressing the most significant remaining drinking water risks first and optimizing risk reduction to the public. The 1996 Amendments fundamentally changed the process for identifying new contaminants for regulation and the standard-setting process. Section 1412(b)(1)(A) of the 1996 SDWA details the three criteria for identification of new contaminants for regulation: 1. The contaminant may have an adverse health effect; 2. The contaminant is known or likely to occur at levels of public health concern; and 3. Regulation provides a meaningful opportunity for health risk reduction.

Several new requirements were added in Sections 1412(b)(3), (4), and (5), requiring that, in developing drinking water regulations, USEPA must use the best available, peer-reviewed science; present information for the public on the risk for the affected population and any uncertainties with that risk; publish a health risk reduction and cost analysis including quantifiable and nonquantifiable costs and health benefits; list affordable small system treatment technologies that achieve compliance; minimize the overall risk by balancing risks from other contaminants; take sensitive subpopulations such as infants, children, pregnant women, the elderly, the immunocompromised, etc., into account; and determine whether the benefits of the regulation justify the costs.

Section 1412(b)(6) gave the USEPA Administrator the discretionary authority to set the MCL at a level "...that maximizes health risk reduction benefits at a cost that is justified by the benefits..." if the benefits of the MCL that is as close as feasible to the MCLG would not justify the costs.

All of the above changes have significant impacts on the regulations, but the discretionary authority is probably the most significant. The USEPA now had significant latitude in setting an MCL and the determination of costs and benefits, and the inherent uncertainties underlying both, became more important in the standard-setting process.

The 1996 SDWA Amendments also added a requirement for USEPA to review existing drinking water regulations every six years to take into account new health effects, analytical methods, occurrence data, and treatment data. Additionally, statutory deadlines were set for priority regulations such as arsenic and radon and a group of regulations known as the Microbial/Disinfection By-Product (M/DBP) Cluster.

Implementation of the 1996 SDWA Amendments. Since the 1996 SDWA Amendments, EPA has finalized another nine drinking water regulations: Stage 1 Disinfectants/Disinfection By-Products Rule (DBPR) (*12*); Interim Enhanced Surface Water Treatment rule (IESWTR) (*13*); Radionuclides Rule (*14*); Arsenic Rule (*15*); Filter Backwash Recycling Rule (FBRR) (*16*); Long-term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) (*17*); Stage 2 Disinfection By-Products Rule (DBPR) (*18*); Long-term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) (*19*); and Groundwater Rule (GWR) (*20*).

These nine regulations increased the number of regulated contaminants to 91. This may not seem like a significant increase from 84 regulated contaminants since the phase V Rule in 1992 (an 8.3% increase), but these regulations addressed some significant drinking water risks. The new arsenic standard was a 5-fold reduction from the old standard, with the standard being lowered from 50 μg/L to 10 μg/L. The IESWTR, LT1ESWTR, and LT2ESWTR addressed the risks from *Cryptosporidium,* a newly recognized drinking water pathogen when compared to typhoid and cholera.

The exposure to disinfection byproduct (DBPs) is significant since most source waters contain natural organic matter that form DBPs when disinfectant is added to kill pathogens. USEPA started regulating DBPs in 1979 with the TTHM Rule, as the Agency concluded that chloroform caused cancer. In 1998, the Stage 1 DBPR lowered the existing numerical standard for TTHMs from 100 μg/L to 80 μg/L; added new standards for five haloacetic acids (HAA5), chlorite, and bromate; and established Maximum Residual Disinfectant Levels (MRDLs) for chlorine, chloramine, and chlorine dioxide. In 2006, the Stage 2 DBPR shifted compliance from a running annual average (RAA) across the distribution system to a locational running annual average (LRAA) at each sampling location to provide equitable protection across the distribution system. These two rules also made these standards applicable to all systems as opposed to the TTHM Rule that only applied to systems serving >10 000 people.

Eight of the nine regulations (all except the Radionuclides Rule) had statutory deadlines in the 1996 SDWA Amendments. Five of the nine regulations (Stage 1 D/DBPR, IESWTR, LT1ESWTR, Stage 2 DBPR, and LT2EWSTR, also known as the M/DBP Cluster) resulted from a series of negotiated rulemakings and Federal Advisory Committee (FAC) processes, so USEPA only had to build upon what had been agreed upon in completing the final rule. The FBRR was a relatively simple rule, so radionuclides and arsenic provided the first opportunities to see how the discretionary authority given to the USEPA Administrator for setting standards by the 1996 SDWA Amendments impacted the selection of the MCL.

The uranium MCL was the first time that USEPA invoked the discretionary authority of Section 1412(b)(6) of the SDWA to set the MCL at a level higher than the feasible level. In 1991, USEPA proposed an uranium MCL of 20 μg/L based on kidney toxicity and carcinogenicity (*21*). New kidney toxicity analyses prompted USEPA to publish a Notice of Data Availability (NODA) in April 2000 and to request comments on three regulatory options for a uranium MCL (20, 40, and 80 μg/L) with their associated costs and benefits (*22*). USEPA had concluded that 20 μg/L was the level as close as feasible to the uranium MCLG of zero. However, in December 2000, using the discretionary authority previously mentioned, USEPA found that the benefits do not justify the costs at the feasible level (20 μg/L); an MCL of 30 μg/L maximizes the health risk reduction benefits at a cost justified by the benefits; and an MCL of 30 μg/L is still protective for

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kidney toxicity and carcinogenicity with an adequate margin of safety (*14*).

USEPA followed a similar path with the arsenic regulation. In 2000, USEPA proposed an arsenic MCL of 5 μg/L and requested comments on alternate MCL levels of 3, 10, and 20 μg/L (*23*). Later in 2000, USEPA published a NODA containing a revised risk analysis for bladder cancer and new risk information for lung cancer (*24*). In 2001, USEPA set the arsenic MCL at 10 μg/L based on the monetized benefits best justifying the costs (*15*).

It should be noted that USEPA's quantified estimates of benefits typically span an order of magnitude or two and have significant uncertainties, while treatment costs typically fall within a narrower band. Therefore, the SDWA allows the USEPA Administrator to consider both quantified and nonquantified costs and benefits, and to use the discretionary authority under the statute to determine if the benefits justify the costs, or if health risk reductions are maximized for any drinking water regulation.

The M/DBP Cluster previously mentioned provides some different policy insights. USEPA elected to use a series of negotiated rulemakings and Federal Advisory Committee (FAC) processes in order to address the risk balancing between DBPs and microbial contaminants. USEPA elected not to use its traditional rulemaking process in the early 1990s to address DBPs due to its concern about potentially increasing microbial risk with stricter DBP standards. Stakeholders recognized that compliance with tighter DBP standards should not be met by reducing and/or compromising disinfection. Yet, due to widespread DBP exposure and continued concern about bladder cancer risk, USEPA was compelled to tighten DBP regulations (*12, 18*). In the preamble for the Stage 2 DBPR, USEPA summarized 22 cancer epidemiological studies and found that "...the available research indicates a potential association between bladder cancer and exposure to chlorinated drinking water or DBPs..." The alternative regulatory processes allowed all of the stakeholders to understand the risk balancing between the acute microbial risk (getting sick from bacteria, viruses, or protozoa) and the chronic cancer risk, and to ultimately develop paired rulemakings where tighter DBP standards were linked with tighter microbial standards.

The Groundwater Rule (GWR) is the most recent national drinking water regulation and addresses microbial risks in groundwater systems (*20*). This rule has significant policy implications, as its implementation requires state primacy agencies to make several regulatory policy decisions based on local conditions. Implementation of the GWR is ongoing, so the ultimate policy implications of this rule are not yet clear.

Finding the Appropriate Contaminants to Regulate. The Contaminant Candidate List (CCL) and the resultant Regulatory Determinations (RDs) are the foundation of the new standard-setting process in the 1996 SDWA Amendments. The CCL is the starting point for the regulatory development process, and the 1996 SDWA Amendments require USEPA to develop a CCL every five years and then subsequently make at least five RDs every five years. USEPA has developed three CCLs and made two rounds of RDs (*25*- *29*). To make sense of the rulemaking process, understanding the details of how the three SDWA criteria are employed to identify the appropriate contaminants to consider for potential regulation and to make appropriate regulatory decisions for those contaminants is critical.

USEPA developed the first CCL (CCL1) in 1998 through an expert process that used the health effects and occurrence data available at that time (*25*). CCL1 listed 60 chemical and microbial contaminants as potential contaminants for regulation. USEPA decided to not regulate nine contaminants in the first RD (RD1) in 2003 because because these contaminants did not occur frequently in public water systems at levels of health concern and/or there was not a meaningful opportunity for health risk reduction through a national drinking water regulation (*26*). Six of these contaminants were found to occur infrequently and did not meet the second criteria, of being known or likely to occur at levels of public health concern.

USEPA also found that three contaminants, sulfate, sodium, and *Acanthomebea*, did not provide an opportunity for meaningful risk reduction. Some explanation of this decision is warranted. The health effects from sulfate are self-limiting (very mild diarrhea for a couple of days). Sodium exposure from food is much greater than what might be found in drinking water. *Acanthomebea* is only a potential issue for contact lens wearers and can be addressed through the appropriate care of contact lenses. So in these three cases, USEPA decided that a national drinking water regulation was not warranted.

The contaminants on the second CCL (CCL2) in 2005 were the 51 remaining contaminants from CCL1 after RD1 (*27*). USEPA again decided to not regulate 11 contaminants in the second RD (RD2) in 2008 as a national regulation did not "...present a meaningful opportunity for health risk reduction..." as required by the 1996 SDWA (*28*). Taking a more detailed look at these 11 contaminants provides some insight into USEPA's policy decisions.

USEPA can require water systems to conduct monitoring to develop occurrence data through the unregulated contaminant monitoring rule (UCMR). This helps the agency to determine if a specific contaminant occurs frequently at levels of health concern nationally. The results from the first UCMR (UCMR1) provided some foundation for USEPA's decision to not regulate the majority of the 11 contaminants in RD2 (*30*). Five UCMR1 contaminants (1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene [DDE], 1,3-dichloropropene [Telone], 2,6-dinitrotoluene, s-ethyl-dipropylthiocarbamate [EPTC], and Terbacil) had zero occurrence in UCMR1 monitoring. One contaminant, 2,4-dinitrotoluene, had 1 detection out of 3479 (0.029%) systems. Clearly, these six contaminants should not have been regulated since these six contaminants do not occur at levels of health concern, which is the second criteria in Section 1412(b)(1)(A) of the 1996 SDWA Amendments. In other words, USEPA listed these contaminants on CCL1 because the Agency thought they might occur in public water systems and might warrant a national regulation. However, occurrence data was needed to determine if the contaminants were in drinking water at levels of health concern, so monitoring was required under UCMR1. However, the contaminants were not found to widely occur, so it was determined that a national regulation would not provide the meaningful opportunity for health risk reduction.

With more time and resources at its disposal, USEPA used a more robust process to build the third CCL (CCL3) in 2009 (*29*). Screening tools were developed to identify a "Universe" of potential contaminants, and more detailed analyses were conducted to narrow the universe to the Preliminary CCL (PCCL). Detailed models and algorithms were then developed to reduce the PCCL to the CCL3. CCL3 lists 104 chemical contaminants and 12 microbial contaminants. EPA is scheduled to make the third round of regulatory determinations (RD3) in 2013.

Since the 1996 SDWA Amendments, USEPA has been trying to find appropriate contaminants to regulate through the CCL/RD processes. USEPA has decided to not regulate 20 contaminants in RD1 and RD2 in accordance with statutory requirements, and those decisions raise some policy issues that will be discussed later (*26, 28*).

While not based on new contaminants, the six-year review of existing regulations required by the 1996 SDWA Amendments provides USEPA another opportunity to make appropriate regulatory changes by taking into account any new relevant health effects, analytical methods, occurrence, or treatment data. In the first six-year review in 2003, USEPA looked at 69 existing drinking water regulations and decided to only revise the Total Coliform Rule (TCR) (*31*). In March 2010, USEPA published a notice on the results of its second six-year review (*32*). Four standards will be revised in the future for acrylamide, epichlorohydrin, tetrachloroethylene (PCE), and trichloroethylene (TCE). Acylamide and epichlorohydrin were selected, as many manufacturers can produce lower levels of the monomer in polymers. PCE and TCE were selected based on improved analytical methods, as these two contaminants have zero MCLGs, and the MCLs set in 1987 were based on analytical feasibility.

Complexities with Recent Regulations. The more recent nine regulations after the 1996 SDWA Amendments also represent a policy shift from the past in that the regulations are becoming more complex (*33*). Most of the 91 currently regulated contaminants are simple numerical MCLs with compliance typically based on an annual average of quarterly samples. Because of the complex nature of the contaminants and the manner in which they occur, the more recent regulations contain more treatment techniques with a more complex compliance determination. In the Stage 1 DBPR, a specific percentage removal of total organic carbon (TOC) is required for sources with TOC >2 mg/L at the same time as compliance with numerical MCLs for TTHMs and HAA5. For example, 35% TOC removal is required for source water with TOC between 2.0 and 4.0 mg/L and alkalinity between 0 and 60 mg/L as $CaCO_3$. This treatment technique was developed to address unknown DBPs contained in the balance of the total organic halogen (TOX). TOCs being relatively easy to analyzes served as an indicator of DBP precursors. The specific percentage of TOC removal is based on the TOC and alkalinity of the influent water, and compliance is based on an annual average of monthly removals.

Additionally, compliance treatment technologies such as ion exchange (IX) or coagulation/microfiltration (CMF) to comply with recent regulations such as arsenic are complex to operate and maintain.

Is the Current Regulatory Process Appropriate for the Next 40 Years? From a policy perspective, one might ask is the current SDWA regulatory process working and is that process appropriate for the next 40 years? In the author's opinion, the answer is a combination of "yes" and "no."

The current SDWA regulatory process has been effective in that 20 contaminants were rigorously considered for possible regulation were identified through the CCL/RD processes. For some contaminants, data was needed to determine the extent of occurrence, and the UCMR mandated collection of this data. Five contaminants were not found at all in the UCMR1 monitoring, and one contaminant was detected in a single instance. For these six contaminants (along with the other 14 in RD1 and RD2), a national regulation clearly did not present "...a meaningful opportunity for health risk reduction..." as required by the 1996 SDWA.

One could argue that the current SDWA regulatory process has not worked in that no new contaminants have been regulated, and there is some merit to that argument. The 1996 SDWA Amendments modified the standard-setting process so that a more rigorous process was required to both select the appropriate contaminant and to select the appropriate numerical standard. A more rigorous process requires more resources and more research, and these are both constrained by the Congressional budgeting process, which is outside of USEPA's control.

The regulatory process has already addressed the "low hanging fruit" through 18 national drinking water regulations. The remaining possibilities for regulation are more complex. Regulations will target contaminants that may not occur everywhere, yet may occur often enough to be perceived as a problem. For example, perfluorooctanic acid (PFOA) is a problem in West Virginia, Ohio, Minnesota, Georgia, and Alabama, where manufacturing or application of perfluorinated compounds occurred. The question of the extent of national occurrence is yet to be answered, but PFOA monitoring is likely for the third UCMR (UCMR3), starting in 2013.

The regulatory process will likely also target contaminants where relative source contribution (RSC) further complicates the standard-setting process. The question here is why would USEPA regulate a contaminant in drinking water when the contribution from food or other sources is much greater? In these cases, regulating it in drinking water may provide minimal risk reduction. For example, nitrosamines are a disinfection byproduct (DBP) that are becoming more of a concern as utilities employ monochloramine to comply with stricter DBP regulations (*12, 18*). Five nitrosamines have been listed on the final CCL3 and some or all of the five are likely candidates for potential regulation as part of the third RD (RD3) in 2013. Six nitrosamines are currently being monitored under the second UCMR (UCMR2) in 2008 - 2010, so high-quality national occurrence data will be generated to support RD3 (*34*). However, a recent paper by two USEPA researchers predicted that the proportional oral intake (POI) of *N*-nitrosodimethylamine (NDMA) from drinking water would be 2.7%, and the concentration from food was predicted to be higher than from drinking water (*35*).

Suggestion for a New Paradigm. A new decision-making paradigm is needed to encourage helpful regulatory actions. Instead of pursuing new regulations with debatable or very small risk reduction, a new priority of the regulatory process could shift to focusing on ensuring compliance with existing drinking water regulations while still using the CCL/RD processes to identify new contaminants for potential regulation.

Violation data is really the only performance metric for the SDWA regulatory program. The significant reduction in waterborne typhoid fever in the early 1900s was relatively easy to observe from a public health perspective. As more drinking water regulations are developed, the risks being addressed are more challenging to observe from a public health perspective (*36*).

USEPA has a goal under its Strategic Plan for 95% compliance with health-based standards. National compliance from 2000 - 2008 has varied from 90.7% - 93.6%, which is close to 95%, but not quite there (*37*). The highest national compliance percentage of 93.6% in 2002, and that was the highest percentage since 1993. However, MCL violations from three of the recent regulations have jumped in the past few years, and may continue to increase in future years: radionuclides, violations increased from 443 in 2002 to 1197 in 2009; arsenic, violations increased from 36 in 2002 to 2424 in 2009; and Stage 1 Disinfection By-Product Rule (DBPR), violations increased from 31 in 2002 to 3558 in 2009.

Looking at the trends in the past few years, the number of violations for the arsenic rule and the Stage 1 DBPR increased significantly between 2008 and 2009, and that trend may continue awhile. However, the number of violations for the radionuclides rule decreased from 1308 to 1197 in the same time frame. This is the first positive trend in the recent violation data.

More stringent regulations such as the Stage 2 DBPR will likely increase the national violations numbers once the effective date for this regulation arrives. Some systems that were just barely able to comply with the Stage 1 DBPR standards will likely not be able to meet the Stage 2 DBPR requirement that compliance is measured at each compliance monitoring location as opposed to being able to average across the distribution system. The effective dates for compliance with the Stage 2 DBPR are staggered based on system size but start on April 1, 2012 for systems serving >100 000 people. While the Stage 2 DBPR is not likely to pose a substantial compliance problem for some large systems, it could potentially be a significant compliance problem in 2013 or 2014 for the systems serving <10 000 people that are still figuring out how to comply with the Stage 1 DBPR.

But one might ask why 95% compliance is the ultimate goal? Would an airline passenger be comfortable riding in a plane that was 95% reliable? Why not 99% or 99.9%? In the Surface Water Treatment Rule, USEPA requires 99.9% inactivation of viruses, so why not consider that (or another number) as a goal for compliance?

The answer is likely this: Reality creeps in when talking about increasing the compliance percentage, because most of the violations are from small systems with limited financial resources. Systems serving <500 people had approximately 54% of MCL violations and 64% of all violations in 2009 (*37*). These very small systems comprise 56% of the community water systems (CWSs), so the two violation percentages bracket the percentage of systems. Generally, the percentage of MCL violations and total violations for each system size category follows the percentage of systems in each size category.

Resource Needs and Constraints. From a national perspective, the funding gap between water system needs and resources is significant. Two estimates by USEPA give some perspective on the issue of water infrastructure funding. In 2002, USEPA estimated the gap between the projected needs and the current funding levels for wastewater and drinking water utilities for a 20-year period (*38*). Assuming average revenue growth, this report found the gap in clean water funding to be $21 billion and to be $45 billion for drinking water.

In 2009, USEPA released its fourth Drinking Water Needs Survey and Assessment to determine the 20-year capital investment needs for water utilities (*39*). The survey found the total national drinking water needs to be $334.8 billion for 2007 - 2026, with $200.8 billion needed for transmission and distribution and $75.1 billion needed for treatment. The transmission and distribution needs are almost three times the treatment needs, showing that delayed infrastructure investment is more problematic than new regulations, assuming that most of the treatment needs are driven by the new regulations.

The Drinking Water State Revolving Loan Fund (DWSRF) is often touted as the nation's water infrastructure funding solution. But in reality, the annual appropriations by Congress for the DWSRF are miniscule compared to the needs. The typical DWSRF funding since its inception has been slightly under $1 billion annually, and the FY 2010 national appropriation of $1.387 billion is higher than past funding. However, even at the higher level of FY 2010 funding, the annual DWSRF appropriation is approximately 0.4% of the 20-year need based on the 2007 Drinking Water Needs Survey. Even if the higher FY 2010 of the DWSRF appropriation were to be maintained for the next 20 years, the total appropriations would be approximately 8.3% of the total funding need. Furthermore, even though the DWSRF has provisions for no-interest or negative-interest loans, the loans eventually have to be repaid, and the rates for the consumers have to support the repayment of these loans. So federal funding is not, nor should it be, the total solution for infrastructure funding needs.

From a water system perspective, raising rates is the local solution, but the funding gap is especially acute for small systems. For example, consider a small system serving 500 connections or approximately 1500 people. This example system would have annual revenues of $180 000 assuming a $30/month water bill. Now suppose this system had to rehabilitate a mile of pipes that could cost in the range of $500 000 to $1 million, depending on many local factors. This one single rehabilitation project would cost approximately three to six times the system's annual revenue.

Other factors can compound the challenge. Suppose the system also needs to install ion-exchange treatment on its well to comply with a state-based perchlorate standard. Assuming a well that produces 300 gallons per minute (gpm), the capital cost for ion-exchange would be approximately $400 000. The operation and maintenance (O&M) cost would be approximately $0.63/1000 gallons, and these O&M costs would continue in perpetuity.

Limited financial resources are not just a small system issue. While large cities have larger overall revenues, water system infrastructure improvements must compete with other priorities in cities' budgets such as fire, police, schools, etc. Many large cities have a substantial portion of residents with limited incomes that puts pressure on the elected officials to minimize rate increases.

State primacy agencies are also suffering from resource limitations. In 2003, the Association of State Drinking Water Administrators (ASDWA) released a report on the funding gap for the states' drinking water programs (*40*). This report found a funding gap in 2002 of approximately $230 million between the funds expended at the state level for their drinking water programs and the estimated $535 million needed. The funding shortfall was estimated to increase to approximately $369 million by 2006, and this shortfall will continue to grow as the number of regulations increase, the population increases, and water systems expand. These agencies are being further hurt by the recent economic downturn, as many states have instituted hiring freezes and some have mandated furloughs to reduce budgets.

Put simply, more financial tools beyond the DWSRF, such as infrastructure banks and less restrictions on private activity bonds, are needed to help systems lower the cost of capital and address true needs. States also need more resources and charging fees for services to systems compounds the financial problems systems face. If political pressure pushes USEPA to actively pursue new regulations with significant uncertainties in public health protection, then the agency will have to recognize the constraints of its own limited resources and the compliance challenges of utilities.

What's Next for the SDWA? The SDWA has worked successfully over the past 40 years in that the significant risks remaining after the widespread adoption of filtration and disinfection in the early 1900s have been addressed. The nine regulations published by USEPA after the initial 1974 SDWA and the nine regulations published after the 1996 SDWA Amendments addressed risks from many natural chemicals such as arsenic and radionuclides, from many man-made chemicals such as pesticides and disinfection byproducts, and from pathogens such as *Giardia lamblia*, *Cryptosporidium parvum*, and *E. coli*.

Looking back at environmental improvements on the 40th anniversary celebration of Earth Day on April 22, 2010, smog levels have been reduced by 25% and lead levels in air have been reduced by 90% (*41*). Remaining environmental issues are more subtle, and the risk reductions are therefore more subtle, than those 40 years ago, such as the Cuyahoga River fire in 1969, noting that this area is a waterfront attraction for Cleveland now.

The improvements to drinking water quality over the past 40 years have followed a similar path in that many significant risks have been addressed, but some residual risks still remain. Those remaining risks need to be identified and appropriately addressed. The current CCL/RD processes provide the foundation for addressing this risk by identifying additional contaminants that might be a public health concern and collecting the appropriate health effects and occurrence data to determine if a national regulation "...provides the meaningful opportunity for risk reduction..."

Improvements to analytical technologies increased detections in drinking water and detection does not necessarily indicate a health effects issue. The regulations have generally targeted contaminants in the μg/L range over the past 40 years, and instrumentation detecting in ηg/L is becoming more common in environmental laboratories. Contaminants are now being found that previously went undetected. Recent media stories about detections of pharmaceuticals in drinking water typically do not have any public health context and can increase public concern about drinking water safety (*42*). Some look at USEPA not regulating any new contaminants from CCL1 and CCL2 as a sign that the regulatory process is working and needs to be changed.

On March 22, 2010, USEPA released a new approach to protecting drinking water and public health (*43*). The agency announced it is seeking to expand public health protection by going beyond the traditional regulatory framework of addressing contaminants one at a time and look at regulating groups. The three additional components of the strategy are to foster development of new drinking water technologies to address health risk posed by a broad array of contaminants; use the authority of multiple statues to help protect drinking water; and partner with states to share more complete monitoring data from utilities.

Regulating groups is the most interesting part of the strategy from a policy perspective as grouping has been used on a limited basis in the past. For example, the TTHM Rule in 1979 grouped the four trihalomethanes together and the Stage 1 DBPR grouped five of the nine haloacetic acids together under the HAA5 MCL. How contaminants might be grouped together in the future will be interesting, would they be grouped by health effects end point, chemical structure, treatment technology, or analytical method?

One can make a good case for a more streamlined standard-setting process, and also for increased investment in the underlying health effects and occurrence research. A recent retrospective analysis on the amount of research completed by the time the regulation was finalized found that the many of the research tasks in USEPA's arsenic research plan were not completed by the time the arsenic rule was finalized (*44*). This same paper analyzed the research resource needs for the CCL/RD processes and found, given USEPA's current research funding levels, more than 20 years would be needed to conduct the necessary research. This time frame does not match up with the required five-year CCL/RD cycles, and USEPA is faced with making difficult decisions on the remaining risks with limited information.

From a utility perspective, drinking water will continue to be treated, disinfected, and reliably distributed every day, with or without changes in the regulations. Challenges will remain in balancing the financial demands of new capital construction, rehabilitation of existing infrastructure, and ongoing operations and maintenance with the financial constraints of communities and the drinking water consumers. The infrastructure funding gaps will continue to present a challenge whenever significant treatment to comply with a regulation is considered.

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